INTERACTION OF LEARNER CHARACTERISTICS WITH LEARNING FROM ANALOGICAL MODELS OF THE PERIODIC TABLE AND WRITTEN TEXTS

BY

JEFFREY RICHARD LEHMAN

A DISSERTATION PRESENTED TO THE GRADUATE COUNCIL OF THE UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

UNIVERSITY OF FLORIDA

1982

To my parents, brothers, sisters, and my wife

ACKNOWLEDGMENTS

I wish to express deep appreciation to the faculty members who contributed to the realization of this study: Dr. John J. Koran, Jr., supervisory committee chairman, for the time he spent sharing ideas and reading the manuscript; Dr. Mary Lou Koran for help in the conceptualization of the aptitude-treatment interaction aspect of the study; Dr. Mary Budd Rowe for helpful suggestions with regard to the theoretical basis of the study; Dr. James Algina for support during the statistical analyses of the data; Dr. William Hedges for useful suggestions for enhancement of the literature review chapter; and Dr. Robert Wright for many helpful suggestions throughout the writing of the dissertation.

Special appreciation is extended to Dr. Eugene Todd for providing me with a teaching associateship throughout my graduate studies. The experience gained in Dr. Todd's department was most rewarding.

Finally, I wish to thank Sue Kirkpatrick for typing the manuscript, and my wife, Kathy, for being supportive and patient during my graduate studies.

TABLE OF CONTENTS

Page

LIST OF TABLES

Table		Page

LIST OF FIGURES

Abstract of Dissertation Presented to the Graduate Council of the University of Florida in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy

INTERACTION OF LEARNER CHARACTERISTICS WITH LEARNING FROM ANALOGICAL MODELS OF THE PERIODIC TABLE AND WRITTEN TEXTS

By

Jeffrey Richard Lehman

May, 1982

Chairman: Dr. John J. Koran, Jr.
Major Department: Curriculum and Instruction

This study was designed to explore the effects on learning of structural modifications to the periodic table. Subjects received a traditional periodic table, a table with added numerical data, or a table with added visual data. Subjects used their periodic table alongside corresponding written materials or were required to turn to the back of their written materials to use the table as they might in a textbook. Another purpose of the study was to examine the effectiveness of including in the written materials a two-page schema showing relationships between the topics explained in the written materials and the periodic tables. Finally, the interaction of learner characteristics with these treatments was explored.

One hundred and sixty high school students were randomly assigned to one of eight treatments in a modified posttest

only design. Subjects were given aptitude tests representing verbal comprehension, associative memory, prior science knowledge, and fluid ability, which were thought to be differentially related to learning in each of the treatments, in addition to the treatment materials and posttest measure.

For the purpose of analysis, subjects were stratified into two groups based upon previous experience with the periodic table. Regression analyses revealed that for subjects with minimal experience with the periodic table, those who received the table with added visual data performed significantly better on the forced (multiple) choice posttest items than subjects who received either of the other two tables. No significant effects were detected for the location of the table or the presence of the two-page schema.

For subjects familiar with the periodic table, no significant main effects were found for type of table, location of table, or the presence of the schema. However, significant vocabulary x table and vocabulary x location interactions were detected when the dependent measure was the multiple choice portion of the posttest. Subjects high in verbal comprehension tended to take advantage of the features of the modified tables, while those low in verbal comprehension processed the traditional table with less information most effectively. Subjects low in verbal

comprehension also benefited more from having the periodic table alongside their written materials.

CHAPTER I
THE PROBLEM

Purpose

The primary purpose of this study was to ascertain the differences in learner achievement in chemistry resulting from variations in the periodic table as students used differently constructed tables to solve chemistry problems. An additional purpose of the study was to examine the interaction of learner characteristics with the treatments presented.

Specifically, instructional materials were modified by placing with the written materials (1) a traditional periodic table, (2) a periodic table with added numerical information, or (3) a table with added visual information. Furthermore, subjects either used the periodic table removed from the associated written materials or were instructed to keep the table attached to the back of the materials as is usually the case in chemistry textbooks. Finally, some subjects also received a two-page schema which provided a structural network identifying the relationships between the chemistry topics explained in the instructional materials. It was expected that these treatment variations would differentially affect the acquisition of information from the written materials, and variations in learner characteristics would influence posttest performance in each treatment.

Background to the Problem

Ever since Aristotle's attempt to classify the elements known during his time, scientists have attempted to organize the chemical elements. These attempts have produced the single most used visual aid in chemistry instruction today—the periodic table of the elements. Today's table was designed to help users of the table systematically organize observed trends in chemical behavior which might otherwise appear unrelated (Hyde, 1975).

There are many chemical as well as physical properties of elements that can be related by using the periodic table. An element's properties, such as atomic number, atomic mass, number of isotopes, type of bond formation, electron configuration, state of matter, and relative size, can be incorporated into the periodic table. In fact, chemistry journals have contained numerous articles advocating the modification of the traditional periodic table which contains only the chemical symbol, atomic number, and atomic mass. Mazurs (1974) provided an extensive review of the proposed representations of the periodic table that appeared in print between 1869 and 1969. Over 700 tables were published which Mazurs grouped into 146 types and subtypes. These modified tables were designed for specific topics in chemistry instruction or for chemical research. Not only have scientists disagreed over the type and amount of content that should be emphasized on the table, but they have also disagreed

over the form the table should take to best show the periodic relationships (Shoemaker, 1958). Yet with all the interest in the periodic table, few educators or publishers have explored how the table could be modified or used to result in greater learning from it.

Modified Tables

The shape of the traditional long form of the periodic table, which has the transition elements located between the main group elements, has undergone various modifications. These modifications included Scherer's (1949) spiral periodic table, Clauson's (1952) space model of the periodic system, Rice's (1956) helical periodic table, Kow's (1972) octagonal prismatic table, and Hyde's (1975) lobed periodic table. In each of these cases the overall shape of the table was modified to highlight specific relationships between elements.

Scientists have also modified the traditional table by altering the amount of information presented within each block on the table. Reese and Meek (1961) proposed a revolving block model of the periodic table. Noting the difficulty of crowding mass data into small two-dimensional blocks, they provided information on all four sides of three-dimensional blocks which the students then used. McCutcheon (1950) attempted to modify the traditional table to include more information by preparing a series of flaps containing different elements. By the appropriate selection of flaps he discussed specific elements and relationships that were

relevant at that particular time. In neither case, however, was an attempt made to determine whether students learned more from the periodic tables modified by the addition of information.

Besides modifications in the form of the table and amount of information on the periodic table, scientists have also modified the traditional periodic table by using color, displaying the relative sizes of the atoms, and by using notational cues. Bean (1980) and Campbell (1946) used color to distinguish between metals and nonmetals as well as to represent elements' relative densities. Guenther (1970) utilized color to show relationships in the electronegativities of elements, while Hyde (1975) used color coding to indicate relationships between groups of elements. Regardless of the property stressed, the use of color permitted these scientists to distinguish quickly between groups of elements based on a specific property.

The relative atomic sizes of the elements have also been included on many modified tables. Klingenberg and Springman (1952) stated that useful correlations could be drawn between the sizes of atoms and ions and their physical and chemical properties. Consequently, a useful table should include the relative sizes of atoms. Such tables were proposed by Cambell (1946), Klingenberg and Springman (1952), and Sanderson (1956).

Finally, Szabo and Lakatos (1957) noted that the periodic relationships of the properties of the elements depended not only on the number of electrons in the neutral atom, but also on an element's electron configuration. Attempts to illustrate electron configurations with notational cues placed above columns of elements or within each block on the table were proposed by Eichinger (1957), Emerson (1944), Hyde (1975), Miller (1955), Simmons (1948), and Wagner and Booth (1945). However, none of the above variations (using color, displaying the relative sizes of the atoms, or including notational cues on the table) were specifically derived and developed to accommodate different types of student characteristics nor were the variations derived from underlying theories of learning.

As expected, no single table completely satisfied the interests of everyone. The modified tables mentioned previously were developed for specific chemical research or instructional topics. All of the tables were artificial attempts to organize approximately 100 unique elements in the most logical way in order to compare the elements' properties (Sanderson, 1954). Regardless of the table developed, the main purpose was to draw the user's attention to trends in the properties of elements. It was generally assumed that the resulting generalizations derived from the table enabled students to infer properties about specific elements based upon a knowledge of the properties of groups of

elements. Yet with all the interest shown in the periodic table and ways to modify it, not a single educational research study was performed to determine the relative effectiveness of the different periodic tables for different types of learners. Instead of continued opinion guiding the design of tables, research is needed to help determine which types of periodic tables are most appropriate for specific topics and for particular types of learners.

Use of the Table

Instructors have used the periodic table to draw attention to regularities in various physical and chemical properties of the elements. For instructional effectiveness the content of the table should correspond with the topics being taught in chemistry classrooms. In a pilot study of 103 second-semester chemistry students at the high school level, students listed all of the types of information they could obtain from the periodic table. The most common responses included the atomic mass of an element, the atomic number of an element, and the element's chemical symbol. These three pieces of information are found on the traditional periodic table. Other frequent responses included the metallic or nonmetallic nature of an element, the element's electron configuration, and the reactivity of an element—all qualitative properties of elements. These qualitative properties are not directly obtained from the traditional table, but students can derive them by

possessing a thorough knowledge of atomic structure and then transferring that knowledge to the table. When comparing the information listed by these students with topics contained in current chemistry textbooks, there was substantial agreement. Therefore, beginning research on modifications to the traditional periodic table might focus on such properties as metals and nonmetals, chemical reactivity, and the electron configurations.

Summary

Although many scientists have advocated modifications to the traditional periodic table, no attempts were found that investigated the effectiveness of learning from such tables. Because students are expected to use the periodic table throughout the school year to answer questions covering a wide range of chemistry content, research is needed to guide the development of periodic tables. The resulting tables would be appropriate for specific topics and particular types of learners, and the provision of schema may make the written materials more useful by providing a linking structure between the written materials and the periodic table.

CHAPTER II
REVIEW OF RELATED LITERATURE

Cognitive Theory

During the past two decades an increasing emphasis has been placed on cognitive rather than behavioral interpretations of learning during instruction (Wittrock, 1979). As part of this emphasis, students were no longer viewed as passive learners in a stimulus-response setting but rather as actively processing information between the presentation of a stimulus and the corresponding response. In this context the internal activities that students performed after being exposed to a stimulus included categorizing, devising mnemonic devices, incorporating new information with prior learning, and reviewing (Armbruster & Anderson, 1980). All of these strategies functioned to help students structure and process new information.

Another type of strategy designed to help students structure and process information has been the use of analogy. Because students have traditionally had difficulty in processing science topics such as atoms, electricity, and light, analogy has been explored as a mechanism to facilitate this processing. Although the use of simple analogy has generated much interest among cognitive psychologists (Sternberg, 1977; Tversky, 1977; Verbrugge & McCarrell,

1977), little research attention has been given to science analogies due to their complexity. Recently, though, Gentner (1980) provided a theoretical treatise in which complex analogies were treated as structure mappings between two content domains. The attributes of objects as well as the relationships between objects in one of the domains must be familiar to learners. Learners process content in the second domain by mapping, or transferring, their knowledge of the first domain to the second domain.

As an example of a science analogy, Gentner considered Bohr's model of the atom. Here the familiar domain is the solar system which consists of the sun and planets. The planets are also known to rotate and revolve around the sun. The atom is the domain to be processed. If mapping is successful, learners make the nucleus analogous to the sun and electrons analogous to the planets. Thus, the view of the atom becomes electrons rotating and revolving around a more massive nucleus which is at the center of the atom.

In order to use science analogies effectively, students must determine whether the attributes of the objects, the relationships between objects, or both attributes and relationships are the key features of the analogy to be transferred between domains. In this regard, Gentner (1980) found that subjects generally compared relationships between objects to a greater degree than the attributes of objects when given an analogy. In fact, subjects stated

that a comparison for which only attributes could be found was a poor analogy. Consequently, Gentner argued that a good analogical model in science was one that provided for a predominance in the transfer of relationships between content areas.

Other researchers have investigated the importance of relationships in the storage and retrieval of information in related areas. Chase and Simon (1973) investigated strategies used by chess players of varying abilities. Expert chess players reconstructed a chess board significantly better than novices when the pieces were in positions from an actual chess game. However, when the chess pieces were placed at random on the board, the expert's performance was similar to the performance of the novice. Simon (1974) suggested that experts chunked familiar stimuli to form a series of patterns which were later recalled from memory. In so doing, experts reduced the memory burden created by large amounts of information.

More recently, Larkin (1979) proposed that science experts stored principles as a group, forming a chunk of connected material. Evidence for this hypothesis was obtained as novice and expert physics students solved physics problems. Larkin noticed that experts generated solutions to problems in bursts while novices appeared to generate principles at random. Larkin reasoned that whenever experts accessed a principle from memory, they immediately had

available all other principles related to the first principle in the chunk. Thus when a principle was generated, there was a high probability of several other principles being generated. Novices, on the other hand, had not yet developed a linking network which permitted the chunking of related stimuli. Since principles were probably stored individually, accessing one principle from memory did not make it easier to access others.

In follow-up work, Larkin (1980) recorded verbal accounts of experts and novices as they thought aloud during the solutions of problems. The most obvious difference between novices and experts was the greater amount of knowledge that the experts possessed. This knowledge was organized into a network of relationships and served to direct the experts in a short time span to the relevant parts of the knowledge store. Again students who developed a knowledge structure based on relationships between objects appeared to process more information successfully.

These lines of research in expert-novice thought processes are applicable to the question studied here. Students retrieve factual information from the periodic table. This information includes the element's chemical symbol, atomic number, and atomic mass. Students must then construct a network relating both these properties and the data derived from each of the properties. Because most high school students have minimal experience with the periodic table,

they can be considered novices. For these students, the task of integrating large amounts of information from the table places a burden on the students' processing strategies.

At the same time, Gentner's (1980) work suggests a procedure for reducing these processing requirements. The periodic table can be considered an analogical model of the written materials. Although the table is a condensed version of the content contained in textual form, the relationships between content topics are identical in both text and tabular form. The question then becomes whether or not the structure of the traditional periodic table helps students match the written content with the table and ultimately facilitate processing of the table. If this matching occurs, then processing the information from the table becomes less complex. On the other hand, if students do not perceive the match between textual materials and the table, then they may be overwhelmed by the information load. By modifying the traditional periodic table, educators may help students structure and process the information from the table.

Although educational research studies investigating student learning from the periodic table are lacking, researchers have investigated learning from another visual adjunct, namely, graphs. Research in this area seems pertinent to the problem at hand because the periodic table

contains material in graphic form. At the same time, graphs and the periodic table are both condensed versions of material generally presented in many pages of text. Also, both are visual adjuncts within instructional materials and both contain predominantly factual, numerical data. Thus, research investigating subjects' ability to use graphs may provide ideas concerning subjects' use of the periodic table.

Learning from Graphs

In an early study investigating subjects' success in using graphs, Vernon (1946) found that adults had considerable difficulty remembering and understanding numerical data presented in graphic form. In addition, the less educated subjects appeared perplexed by the graphic displays and tended to ignore or transform the data to fit preconceived ideas. Even the more educated subjects who successfully abstracted factual information had difficulty forming a general statement encompassing the information obtained from a series of graphs.

In a follow-up study, Vernon (1950) compared the effectiveness of a chart, a graph, and a table of figures. Although subjects answered specific factual questions quite well from all three displays, none of the displays were very effective in facilitating higher levels of learning. The failure of subjects to answer inferential questions suggested that they had not acquired the level of understanding

necessary to produce generalizations or to relate facts together. This inability to process information was again found during the 1972-1973 National Assessment of Education Progress results (Carpenter, Coburn, Reys, & Wilson, 1978). When asked a factual question from a graph, 91% of 13-year-olds answered it correctly. But when the question required subjects to interpret a relationship only 45% of 13-year-olds, 65% of 17-year-olds, and 63% of adults answered the question correctly. It appears, then, that subjects use graphs predominately for factual information.

There is no reason to believe that subjects would not use the periodic table in the same way, as a visual organization of facts. Because there are few links between properties provided on the traditional table, its design places the burden of information processing on the learner. By including the relative size of the atoms, the number of outer shell electrons, and the electron configuration directly on the table, a more complete content structure would be provided. This added information could produce two effects. If students perceive only additional information within each block, then the display would become more complex. The added information processing requirement could retard learning. If, on the other hand, the information is presented so that students perceive the relationships in the content, then the table would become a richer display and function to help students process the information. Research findings

based on the use of other visual adjuncts may produce suggestions on how to add more information to the table effectively. Ideally, the resulting modifications would make the table match more closely the written instructional materials.

Modifications to Visuals

Another line of research relevant to the present problem is pictorial research. This work also complements that of Armbruster and Anderson (1980), Gentner (1980), and Larkin (1979) in that its major thrust has focused on ways to help learners process information from complex stimuli. A recurring theme here has been the amount of realism contained in visuals. Carpenter (1953) expressed the opinion that materials which were highly similar to the ideas, objects, or events they referred to were more effective instructional materials than visuals that had little similarity to their referents. Travers (1967) expressed the opposite viewpoint. Since subjects were perceived as being capable of processing only some of the stimuli in a visual display, learning was thought to be facilitated when presentations were reduced in complexity. More recently, two areas of pictorial realism have received much attention. First, researchers have investigated the use of color versus black and white in pictures. The second area of research has focused on the amount of detail subjects viewed.

In a recent review, Chute (1979) reported that the effectiveness of color cuing has produced inconclusive

results. Although learners generally preferred color versions to black-and-white versions, they did not necessarily learn significantly better from color versions (Winn & Schieman, 1977). Other researchers found that color enhanced learning when it was used to emphasize relevant characteristics and aided in organizing stimuli for appropriate discriminations to be made (Berry, 1977; Norman & Rieber, 1968).

Thus it appeared that the function color served in the visual was important since the mere inclusion of color did not enhance learning from the visual materials. It seemed that color's importance rested primarily on the degree to which it facilitated for the learner the organizing and structuring of the presented stimuli. Color can be expected to increase learning from visuals if it is used to highlight relationships between objects and to facilitate quick visual discriminations.

Similar research results were found when researchers varied the amount of detail presented in pictures. The most common result was no differences in learning from visuals with little or much detail. Wicker (1970) found no differences between photographs and line diagrams when used as stimulus materials in a paired-associate learning task. Wheelbarger (1970) found that the addition of shading to line diagrams did not enhance learning compared to the line diagrams themselves. Finally, Dwyer (1976) indicated that

the addition of realistic detail in visualizations did not automatically improve instruction. Dwyer added that the more complex visuals may have produced an information overload for low ability students.

Not all research, however, has produced no significant effects for the addition of detail. Travers (1969) found that the addition of shading to outline diagrams increased the recognizability of the presented pictures. Dwyer (1972) also found that visuals high in realism tended to be more effective when students could control the amount of exposure time to the visuals.

As with color, shading and detail appeared to facilitate learning in situations where the added detail served a purpose. The mere addition of detail did not automatically enhance learning. Only in instances where the added detail readily provided subjects with relevant information did the detail enhance learning from the visuals. The potential use of these widely used variations in visual materials, namely, color and amount of detail, can easily be incorporated into the traditional periodic table. The addition of color and detail can provide a table illustrating relationships between chemistry topics. In this manner an economically efficient way to influence the processing and acquisition of related chemistry material can be achieved. However, by adding more detail to the display, lower ability students may be placed at a disadvantage. Because Zeaman and House

(1963) found that such students have weak attentional and discrimination abilities, the more complex displays may be too burdensome to process. Thus another question to consider is which types of variations in the periodic table are most effective for different content areas and for different types of students.

Aptitude Treatment Interactions

Educational researchers have traditionally sought the "one best" method of instruction to use with an entire class of students. This procedure has been followed although students were known to differ in physical traits, emotional traits, personality, and mental abilities. Recently the search for the "one best" method of instruction has been challenged by a search for alternative ways in which instruction can be presented to more closely fit the characteristics of learners (Cronbach & Snow, 1977; Koran & Koran, 1980). Instead of only varying the time students were exposed to identical methods or varying the educational goals, Cronbach (1965) proposed that subjects receive different instructional methods to reach the same educational goals. Accordingly, he proposed a line of research to explore how different student characteristics might be matched to different instructional treatments. Experimental studies expanding on this idea were called aptitude treatment interaction studies, or ATI. The basic premise behind aptitude treatment interaction studies is that no one educational environment

is best for all individuals, but that different individuals prosper in different environments related to learner characteristics (Koran, 1973).

Cronbach and Snow (1977) defined aptitude as any characteristic of the learner that functioned selectively with respect to learning. Thus, any characteristic that facilitated or hindered learning from some designated instructional method was considered an aptitude. A treatment was defined as anything done to a learner in an instructional setting which included variation in structure, pacing, style, or modality. Generally speaking, an interaction is present when one treatment is significantly better for one type of student, while an alternative treatment is more beneficial for a different type of student. In order for an aptitude treatment interaction to exist, alternative treatments must be designed to meet identical educational objectives. In addition, one or more aptitude measures must be obtained for each subject. Because the general objective of aptitude treatment interaction research is to match instructional methods to learner characteristics, it is necessary to determine under what conditions a particular instructional method would be most effective for particular types or students. Knowledge of such relationships would ultimately provide educators with the basis for individualizing instruction by aptitudes.

Since Cronbach first introduced the concept of ATI, many ATI studies reporting inconclusive results have appeared in the literature. In an attempt to analyze and critique previous research as well as to provide guidelines for future research, Cronbach and Snow (1977) extensively reviewed the ATI literature. They found that general ability interacted more often than other, more specific abilities. In general, methods that used discovery learning, relied heavily on verbiage, were rapidly paced, or required learners to process information largely on their own benefited high ability students while hindering low ability students.

For example, one set of studies contrasted orderly, linear programs with the same frames exposed in scrambled order. The scrambled versions which required students to organize the material for themselves and to select and utilize strategies for doing so generally benefited the more able students while hindering lower ability students (Brown, 1970; Buckland, 1968; Maier & Jacobs, 1966).

Investigators found similar results when subjects attempted to learn relationships in math. Anderson (1941), Orton, McKay, and Rainey (1964), and Thiele (1938) found that treatments that attempted to explain mathematical relationships by leading students to organize the material for themselves benefited students with superior mental ability. Similar findings occurred with grammar as the content.

Fredrick, Blount, and Johnson (1968) divided eighth-grade students into four groups. The first group received written statements explaining concepts in structural grammar. The same concepts were presented in symbolic codes and abbreviations to the second group. For the third group these abbreviations were placed into sentence-tree diagrams which produced "figural" representations of the relationships between the concepts. The final group served as a control. All three treatment groups were superior to the control, and the symbolic and "figural" groups were superior to the verbal group. In addition, the figural treatment appeared to benefit high ability students but was not very useful to low ability students. The authors reasoned that low ability subjects were not capable of interpreting the tree diagrams on their own.

Finally, Allen (1975) reported that learners having a high general ability were usually more capable of processing greater amounts of sensory data than low ability students when confronted with media presentations. All of these ATI studies produced interactions when general ability was considered as the aptitude. In fact, Cronbach and Snow (1977) suggested a measure of general ability be included in all ATI studies. Besides general ability, they suggested that prior achievement, memory, achievement orientation, and anxiety were the most promising variables in studying ATI. After an analysis of the task, two of these, prior achievement and

memory, appear extremely relevant to learning from the periodic table.

Investigating the effects of prior achievement, Salomon (1974) found that students low in relevant visualization skills profited most when shown the skills to be acquired. Students with high relevant abilities performed best when they were permitted to use their own effective skills.

Abramson and Kagen (1975) prefamiliarized half of their subjects with a technical heart disease program. All subjects were then randomly assigned to either a reading only treatment or a treatment requiring constructed responses with feedback. Those subjects who received familiarization performed better under the reading only condition, while the constructed answer treatment benefited subjects not prefamiliarized with the content.

Tobias (1976) reviewed achievement treatment interactions and concluded that the higher the level of prior achievment, the less instructional support was needed to achieve the instructional objectives. Minimal instructional support places the burden of processing stimuli on the learner. Increasing instructional support would focus on ways to organize the stimuli to facilitate student processing. Tobias and Ingber (1976) provided added support for Tobias' instructional support hypothesis. They found that students with a Catholic background benefited more from a constructed responding and feedback treatment than from just reading

about Jewish rituals. There was much less difference between the two treatments for Jewish students. Taken as a whole, it appears that the higher the prior achievement in an area, the more strategies a learner possesses to help process new information and the less outside help is required.

Memory abilities also appear important when considering learning from the periodic table. Memory factors appear to split off from general ability to form a separate ability. Jensen (1969) illustrated this distinction by identifying what he called Level I and Level II abilities. Level I abilities are involved in the formation of associations. Learners perform minimal transformations with the presented stimuli, so the response corresponds highly with the input. Examples include rote memory tasks. Conversely, students who use Level II abilities, actively elaborate and transform the stimulus. These abilities appear more dependent upon what learners already know and processes they can use when presented with a task. Examples are concept learning and problem solving. It appears that students must use both types of these abilities to successfully process the periodic table. Hence, both prior science knowledge and memory abilities seem important when considering the periodic table. Students generally use the traditional periodic table to obtain data given on the table. They must distinguish which piece of data within each block corresponds to the property of interest. The table is also used

to derive information for each element from the given data. Here students must possess a thorough knowledge of science to construct a network of relationships between given data and information derived from that data. Finally, students often compare properties of different elements and develop relationships between groups of elements.

Modifications to the table could alter how students process the information. For instance, adding numerical information within each block may require students to discriminate between more stimuli. At the same time, this added information may reduce the amount of mental elaboration needed to form a network of relationships.

Because many of the properties of elements depend upon atomic structure, an alternative table could include visual representations of atoms. These representations would closely correspond to representations in textual materials. In this way, students should be able to distinguish more easily between the properties of elements. The construction of a network of relationships should also be facilitated.

Regardless of the table used, the location of the table within instructional materials may be important. Typically, textbook publishers place the table at the back of the book. When using the text, students must hold information in memory, turn to the back of the book, recall what to do, perform the task, hold other information in memory, and then turn back to the text. By providing a table adjacent to

the written materials, it appears that publishers could reduce the memory burden associated with using the periodic table.

This process analysis suggests that a measure of general ability, a science knowledge measure, and an associative memory measure may be worthy of investigation. Finally, students use the periodic table to solve problems. The strategies subjects possess and use to solve problems might interact with the type of table used. Thus a measure of fluid ability would seem appropriate.

Summary

The following were the major points derived from the literature reviewed in this chapter and leading to the hypotheses to be tested:

1. An increasing emphasis has been placed on cognitive interpretations of learning during instruction (Wittrock, 1979).
2. Students actively process information from stimuli.
3. Analogies have been used by cognitive psychologists to interpret how students process information (Gentner, 1980).
4. In order to process information presented on the table effectively, students must construct a network of relationships between data given on the table and information derived from it (Larkin, 1979).

5. The structure of the traditional periodic table places most of the information processing burden of using the table along with verbal instruction on the learner.
6. Subjects have not been found to process effectively visual stimuli such as graphs (Vernon, 1950).
7. Reseachers have found that color and amount of realism can be used to make learning from visuals more effective (Chute, 1979; Dwyer, 1972).
8. Color and added information on periodic tables should function to help students structure and process information more efficiently.
9. The location of the table within instructional materials may be an important factor.
10. Learner characteristics may interact with the type of table presented (Cronbach & Snow, 1977).

Taken as a group, these points suggest the efficacy of exploring (1) the effects of structural modifications to the periodic table, (2) the inclusion of schema which provide an analogical model for learners, and (3) the exploration of aptitudes which might make the above differentially effective for learners.

Hypotheses

Based upon previously cited research, the following hypotheses were formulated: (All hypotheses were tested at $\alpha=.05$.)

1. Subjects receiving periodic tables modified by the addition of numerical or visual information will perform significantly better on the criterion measure than subjects receiving the traditional periodic table.
2. Subjects receiving periodic tables not attached to the written materials will perform signficantly better on the criterion measure than subjects receiving periodic tables attached to the instructional materials.
3. Subjects receiving a two-page schema containing a network of relationships designed to help students process the chemistry topics explained in the written materials will perform significantly better on the criterion measure than subjects not receiving a schema.
4. There will be a differential relationship between criterion performance and aptitudes of subjects as measured by the vocabulary, associative memory, science knowledge, and fluid ability measures.

CHAPTER III
EXPERIMENTAL PROCEDURES

Subjects

Tenth-, eleventh-, and twelfth-grade students enrolled in a first-semester, high school chemistry course participated in the study. All subjects attended one of two high schools (N, O) located in the same north central Florida community. Subjects at school N had not been previously taught the periodic table, so the content in the study was relatively new to them. Subjects at school O, on the other hand, had just completed a unit on the periodic table, so the content was old to them. A distribution of the experimental subjects by school and grade level appears in Table 1. One hundred and fifty-eight subjects from seven chemistry classes read the instructional materials, completed the posttest, and completed all four aptitude measures. An additional two subjects completed all of the material except two of the aptitude measures. Data from these 160 subjects were used in all subsequent analyses. Absence from school or reading difficulties prevented an additional eight subjects from completing the experiment.

General Procedures

Subjects participated in the experiment during regularly scheduled 50-minute chemistry classes on three

Table 1
Distribution of Subjects by School and Grade Level

	Grade level		
School	10	11	12
Content new (N)	10	65	23
Content old (O)	29	25	8
Total sample	39	90	31

successive days. The same procedures were followed at both schools during successive weeks. Subjects within each class were randomly assigned to one of the eight experimental treatments.

On the first day subjects received the instructional materials. In addition to written directions, the experimenter briefly gave oral directions to each class. Students were instructed to read carefully the instructional materials, to study the periodic table, and to answer any questions contained in the materials. Students proceeded at their own pace and recorded the time they spent using the instructional materials.

On the second day all subjects received a posttest as well as the same periodic table they used the previous day. The experimenter instructed the students to use the periodic table to help them answer the posttest questions. Data from two of the four aptitude measures were also collected. The remaining aptitude data were collected on the third and final day.

The Design

A modified posttest only design was used to test the hypotheses (Table 2). All eight experimental groups received a set of instructional materials and a delayed (24-hour) posttest. The use of such a design permitted the evaluation of the relative effects each independent variable (type of periodic table, location of table, and presence or absence

Table 2
Experimental Design

Instructional materials	Location	
	Attached (A)	Not attached (NA)
Traditional table plus schema (TS)	TS-A	TS-NA
Table with added numerical data plus schema (NUS)	NUS-A	NUS-NA
Table with added visual data plus schema (VS)	VS-A	VS-NA
Table with added visual data (V)	V-A	V-NA

of a schema) had upon the dependent variable (criterion measure). In addition to main effects, the design permitted investigation of aptitude x treatment interactions.

Treatments

The following is a summary of materials received by subjects in all eight treatment conditions. The materials are explained in more detail following the description of the last treatment.

1. Subjects in treatment one (TS-A) received written instructional materials corresponding to the traditional periodic table. Following the materials was a two-page schema which provided a network of relationships between the topics explained in the written materials. Finally, the traditional periodic table was attached to the end of the packet.
2. Subjects in treatment two (TS-NA) received materials identical to those received by subjects in treatment one. However, the periodic table was detached from the end of the packet and placed beside the written instructional materials.
3. Subjects in treatment three (NUS-A) received written instructional materials corresponding to the periodic table modified with added numerical information. Following the materials was a two-page schema which provided a network of relationships between the topics explained in the written

materials. Finally, the modified table containing added numerical information was attached to the end of the packet.

4. Subjects in treatment four (NUS-NA) received materials identical to those received by subjects in treatment three. However, the periodic table was detached from the end of the packet and placed beside the written instructional materials.
5. Subjects in treatment five (VS-A) received written instructional materials corresponding to the modified periodic table with added visual information. Following the materials was a two-page schema which provided a network of relationships between the topics explained in the written materials. Finally, the modified table containing added visual information was attached to the end of the packet.
6. Subjects in treatment six (VS-NA) received materials identical to those received by subjects in treatment five. However, the periodic table was detached from the end of the packet and placed beside the written instructional materials.
7. Subjects in treatment seven (V-A) received written instructional materials corresponding to the modified periodic table containing added visual information. The modified table was then attached to the end of the packet. No schema was provided.

8. Subjects in treatment eight (V-NA) received materials identical to those received by subjects in treatment seven. However, the periodic table was detached from the end of the packet and placed beside the written instructional materials.

Each of the treatments was comparable to its counterparts in terms of content of written materials and the nature of the schema. The periodic tables were varied in terms of amount, kind, and mode of information presented. The location of the tables also varied; they were either detached for use concurrently or connected to the end of materials as in textbook formats.

Instructional Materials

Subjects in each experimental group received a packet of written instructional materials and one of three periodic tables. In addition, six of the experimental groups received a two-page schema. The schema provided a network of relationships existing between the different chemistry contents discussed in the written materials. Five high school chemistry teachers from four high schools examined all the materials and found them appropriate for high school chemistry students.

Written Materials

Seven to eight pages of written materials explained the following chemistry topics: chemistry and the atom,

electron configurations, formulas of compounds, metals, nonmetals, and trends in the properties of elements. Students learned how to use the periodic table that accompanied the written materials to answer questions pertaining to each topic covered in the written materials.

The initial written materials were field tested in a local high school chemistry class and a local high school biology class. Information from the field test was used to revise those areas of the material that posed problems for the students.

After revision of materials, six high school chemistry students and three high school biology students participated in a pilot test of the materials. These students met individually with the experimenter and read through the materials. The students were directed to note areas of the text that were unclear to them. Students were timed in order to obtain an estimate of the length of time that would be required to complete the study in the schools. In addition, the researcher noted the frequency and amount of time students spent referring to the periodic table. Finally, representative posttest items were given to the subjects and their procedures for answering the items were recorded. From these observations chemistry students were selected as the more appropriate sample because the biology students experienced considerable difficulty with the materials.

A final revision of the materials was conducted. The main modification to the materials was the insertion of 10 questions. The purpose of the questions was to force the students to search the periodic table for answers and to record these answers. These questions were included since the pilot test revealed that students spent very little time referring to the table. Students responded that the periodic table was familiar to them, so they did not perceive a need to study the periodic table accompanying the written materials.

Written materials accompanying the three different periodic tables were essentially identical. Differences occurred only in the addition of a few lines describing the numbers or visual information presented on the modified periodic tables. A Fry (1968) readability estimate on the written materials indicated an approximate reading level of eleventh grade. Examples of the written materials appear in Appendix A.

Periodic Tables

All subjects received one of three periodic tables in addition to the written materials. The first table was a traditional table that contained only the atomic number, the atomic mass, and the chemical symbol of each element. Such a table provided the students with a minimum amount of information and required the students to construct their own network of relationships.

The second table was a modification of the traditional table. Additional numerical information describing electron configuration, the relative size of the atom, and the number of outer shell electrons was provided within each block. This added information produced a potentially richer display for the student to utilize.

The third and final table displayed the same information within each block as the second table. However, the outer electron shell was visually represented with a semicircle and corresponded to the relative size of the atom. The number of outer shell electrons was placed at this shell to stress the importance of atomic structure in determining an element's properties. Finally, each group of elements having similar electron configurations was outlined on the table in a different color. Those elements with their outer subshell completely filled were indicated by shading the semicircle within each block. Examples of the three periodic tables appear in Appendix B.

Schema

The content contained on the periodic table is generally accompanied by much written explanation in chemistry textbooks. Because the explanations of these topics are physically separated by many pages, students may have difficulty perceiving and constructing relationships between the topics. Six of the eight treatments therefore received a two-page schema. The first page of the schema provided a

network of relationships between data derived from an element's atomic number. This information included an element's electron configuration, reactivity, and formulas of compounds.

The second page of the schema identified relationships between groups of elements. Size and reactivity trends were depicted for rows and families of metals and nonmetals. It was anticipated that the schema would help students link and process related principles.

Again pilot test data revealed that subjects spent less than two minutes studying the schema. Consequently, six questions were attached to the schema. These questions were designed to force students to attend to the relationships presented on the schema. The schema and attached questions appear in Appendix C.

Measures

Posttest

All subjects received a 28-item posttest on the day following the reading of the instructional materials. Students used the periodic table they had in the instructional materials to help them answer the posttest items. One portion of the posttest was 14 forced choice, or multiple choice, items. These items consisted of a statement or question followed by four alternative answers. The students were to select and record the most appropriate answer on their answer sheets. The remaining 14 items were equivalent in

content to the forced choice items; however, these constructed answer items consisted of only a statement or a question. Students were expected to use the periodic table to obtain a solution for these items. Reliabilities as calculated by Kuder-Richardson's 21 formula were .51 for the forced choice items, .52 for the constructed answer items, and .72 for the total posttest. The posttest appears in Appendix D.

Aptitudes

Subjects were given four aptitude measures based on an analysis of the instructional task. Three of the measures were taken from the Kit of Reference Tests for Cognitive Factors (French, Ekstrom, and Price, 1963). The tests selected were Vocabulary V-2, First and Last Names Ma-3, and Hidden Figures Cf-1. These tests were designed to measure a student's ability to understand the English language, to remember bits of unrelated material, and to keep one or more definite configurations in mind despite perceptual distractions. A fourth test was developed to measure students' prerequisite factual and conceptual knowledge in science (general science, biology, and chemistry).

All aptitude measures were timed. Students' scores were determined by the correct number of answers. A summary of the aptitude measures and their reliabilities as calculated by Kuder-Richardson's 21 formula are presented in Table 3.

Table 3
Time and Reliabilities of Aptitude Measures

Aptitude	Time	Reliability
Vocabulary	Each part—4 minutes	.59
First and last names	Each part—5 minutes	.79
Hidden figures	10 minutes	.49
Science knowledge	5 minutes	.28

CHAPTER IV
RESULTS

The primary purposes of this study were

1. To investigate the differences in learner achievement when instructional materials varied in (1) the type of periodic table subjects used, (2) the location of the table, and (3) the presence or absence of a schema designed to help students process information and relationships on the table.
2. To investigate the interaction of each of the four aptitudes with the type of periodic table and the location of the table within the instructional materials.

The statistical tests of the hypotheses and the results of the tests will be reported here with the results of the analyses of the instructional treatment main effects followed by the analyses of aptitude x table and aptitude x location interactions. Initial analyses were conducted combining subjects from the two schools. Results revealed no significant main effects and no aptitude x treatment interactions. Subsequently, separate analyses were performed on the data obtained from each school. This procedure seemed warranted because subjects at school O (content old) received instruction on the periodic table just prior to the experimental

study, while subjects at school N (content new) received no previous instruction. All analyses were computed using the University of Florida Statistical Programs Library and the SAS Language Library.

Variables—School N

Instructional materials consisted of seven to eight pages of written materials accompanying a periodic table. Six of the eight experimental groups also received a two-page schema. Data were collected for each group on the number of text questions answered correctly, the number of schema questions answered correctly, and the time spent reading the instructional materials. Cell frequencies, means, and standard deviations for these variables are reported in Table 4.

Scores were also recorded for each subject on the posttest composed of 28 items. This score was subsequently divided into a score for the 14 forced choice items and a score for the 14 constructed answer items. In addition, the length of time students used to complete the posttest was recorded. Descriptive statistics for these variables are reported in Table 5.

Finally, data were collected for each subject on measures of vocabulary, science knowledge, associative memory, and hidden figures. Cell frequencies, means, and standard deviations are reported in Table 6.

Table 4
Instructional Materials Data for School N

Treatment[a]	Text questions			Schema questions			Reading time		
	n	Mean	SD	n	Mean	SD	n	Mean	SD
TS-A	10	9.00	1.25	9	4.22	1.39	10	41.80	5.63
TS-NA	14	8.43	.94	14	4.71	.91	14	37.93	6.28
NUS-A	15	9.07	1.58	15	4.67	1.84	15	40.13	7.13
NUS-NA	11	9.18	1.25	10	5.00	1.15	11	37.73	5.22
VS-A	11	8.64	1.36	11	4.73	1.35	11	36.27	4.05
VS-NA	11	9.27	.79	11	4.91	1.04	11	37.00	8.21
V-A	16	9.38	1.74	--	--	--	16	34.81	6.39
V-NA	10	9.60	.52	--	--	--	10	35.30	7.35

[a]TS-A = traditional table, attached, schema present; TS-NA = traditional table, not attached, schema present; NUS-A = table with added numerical data, attached, schema present; NUS-NA = table with added numerical data, not attached, schema present; VS-A = table with added visual data, attached, schema present; VS-NA = table with added visual data, not attached, schema present; V-A = table with added visual data, attached, no schema; V-NA = table with added visual data, not attached, no schema.

Table 5
Posttest Data for School N

Treatment[a]	Forced choice			Constructed answer			Total posttest			Test time		
	n	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD
TS-A	10	9.20	2.20	10	8.40	3.37	10	17.60	4.93	10	20.50	3.50
TS-NA	14	8.57	3.32	14	8.21	2.12	14	16.79	4.95	14	18.07	3.85
NUS-A	15	9.33	1.95	15	8.20	2.81	15	17.53	4.50	15	20.93	4.33
NUS-NA	11	9.18	2.68	11	8.09	3.05	11	17.27	5.33	11	18.18	2.96
VS-A	11	9.55	2.73	11	9.36	2.77	11	18.91	5.30	11	18.36	2.46
VS-NA	11	11.45	1.29	11	8.73	2.90	11	20.18	3.46	11	16.91	3.56
V-A	16	9.75	2.32	16	9.88	1.75	16	19.63	3.67	16	20.50	3.92
V-NA	10	11.00	1.70	10	9.60	2.72	10	20.60	4.17	10	21.50	4.77

[a]TS-A = traditional table, attached, schema present; TS-NA = traditional table, not attached, schema present; NUS-A = table with added numerical data, attached, schema present; NUS-NA = table with added numerical data, not attached, schema present; VS-A = table with added visual data, attached, schema present; VS-NA = table with added visual data, not attached, schema present; V-A = table with added visual data, attached, no schema; V-NA = table with added visual data, not attached, no schema.

Table 6
Aptitude Data for School N

Treatment[a]	Science knowledge			Vocabulary			Associative memory			Hidden figures		
	n	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD
TS-A	10	14.80	3.05	10	21.00	4.14	10	17.10	5.63	10	4.00	2.00
TS-NA	14	14.07	2.20	14	20.07	2.97	14	19.21	5.63	14	5.07	2.64
NUS-A	15	14.80	2.21	15	21.07	3.94	15	20.93	6.55	15	4.40	1.94
NUS-NA	11	14.36	1.80	11	21.27	3.98	11	17.55	6.39	11	5.00	3.19
VS-A	11	14.00	2.05	11	20.36	3.20	11	21.00	6.50	11	5.09	2.74
VS-NA	11	14.00	3.06	11	20.91	5.70	11	20.09	7.16	11	6.00	2.65
V-A	16	15.19	2.40	16	22.31	6.42	16	20.06	5.57	16	4.13	2.19
V-NA	10	15.20	2.74	10	22.80	4.92	10	19.70	6.48	10	5.40	2.63

[a]TS-A = traditional table, attached, schema present; TS-NA = traditional table, not attached, schema present; NUS-A = table with added numerical data, attached, schema present; NUS-NA = table with added numerical data, not attached, schema present; VS-A = table with added visual data, attached, schema present; VS-NA = table with added visual data, not attached, schema present; V-A = table with added visual data, attached, no schema; V-NA = table with added visual data, not attached, no schema.

Instructional Treatment Main Effects

The following research hypotheses were of major concern relative to instructional treatment main effects.

1. Subjects receiving periodic tables modified by the addition of numerical or visual information will perform significantly better on the criterion measure than subjects receiving the traditional periodic table.
2. Subjects receiving periodic tables not attached to the written materials will perform significantly better on the criterion measure than subjects receiving periodic tables attached to the instructional materials.
3. Subjects receiving a two-page schema containing a network of relationships designed to help students process the chemistry topics contained in the written materials will perform significantly better on the criterion measure than subjects not receiving a schema.

In order to investigate main effects for type of table, location of periodic table, and the presence of a schema, a regression equation was used containing both table and location as components of the regression model. Dependent measures included the forced choice items, the constructed answer items, and total posttest. A summary of F values is presented in Table 7.

Table 7
Summary Table of Dependent Variable Main Effects for School N

Source	df	SS	MS	F
		Forced choice items		
Table	3	46.94	15.65	2.72*
Location	1	7.72	7.72	1.34
Residual	93	534.84	5.75	
Total	97	586.82		
		Constructed answer items		
Table	3	41.08	13.69	2.00
Location	1	2.04	2.04	.30
Residual	93	637.88	6.86	
Total	97	682.69		
		Total posttest		
Table	3	159.79	53.26	2.63
Location	1	1.83	1.83	.09
Residual	93	1880.60	20.22	
Total	97	2040.49		

$*p<.05$.

A significant table effect, F (3,93) = 2.72, was found for the forced choice items. With an error rate per family set at .05, Bonferroni t tests failed to detect the nature of the differences. However, by observing group means and inspecting the confidence intervals produced by the pair-wise comparisons, it appeared that differences existed between subjects receiving the traditional table and subjects who received the visually modified table. The latter subjects performed better than subjects who viewed the traditional table. No differences existed between subjects who viewed the visual table with schema and those who viewed the visual table without schema.

Although the trend was the same as the trend with forced choice items, no significant table effect was detected when constructed answer items were the dependent measure, F (3,93) = 2.00; p = .12. A marginally significant table effect was found for the total posttest, F (3,93) = 2.63. Again Bonferroni follow-up analyses failed to detect the nature of the differences. However, from the confidence intervals produced, it appeared that subjects who received either the traditional periodic table or the table with added numerical information performed poorer than subjects who received the visual table with or without the schema.

There were no significant main effects for location of table detected with any of the dependent measures.

Text Questions, Reading Time, and Test Time

Analyses of variance were also performed using inserted text questions, reading time with the instructional materials, and posttest time as the dependent variables. Summary statistics for all three analyses appear in Table 8.

Text Questions

Subjects in all eight treatment groups received the same 10 questions within their instructional materials. The purpose of these questions was to assure that subjects used all the instructional materials provided. Subjects were required to use the accompanying periodic table to answer the inserted questions. An analysis of variance indicated no significant table x location interaction, F (3,90) = .87; no significant location effect, F (1,90) = .15; and no significant table effect, F (3,90) = 1.15. Hence it appeared that all subjects could answer the inserted questions regardless of the type of table present with the instructional materials.

Reading Time

It was anticipated that subjects not receiving the two-page schema would spend less time with the instructional materials. An analysis of variance on reading time revealed a nonsignificant table x location interaction, F (3,90) = .71; a nonsignificant location effect, F (1,90) = .92; and a significant table effect, F (3,90) = 2.78, p = .045. Follow-up analyses using Bonferroni t tests indicated

Table 8
Summary Table for Analysis of Variance for School N

Source	df	SS	MS	F
		Text questions		
Table	3	7.60	2.53	1.53
Location	1	.24	.24	.15
Table x location	3	4.31	1.44	.87
Residual	90	148.88	1.65	
Total	97	161.63		
		Reading time		
Table	3	344.18	114.73	2.78*
Location	1	38.07	38.07	.92
Table x location	3	88.60	29.53	.71
Residual	90	3719.16	41.32	
Total	97	4194.00		
		Test time		
Table	3	132.34	44.11	3.11*
Location	1	47.15	47.15	3.33
Table x location	3	53.23	17.74	1.25
Residual	90	1275.95	14.18	
Total	97	1507.85		

*p<.05.

that subjects who viewed the traditional table spent a significantly longer time with the materials than subjects who received the visual table without the schema. No other pairwise differences were detected.

Test Time

Analysis of variance on test time indicated no significant table x location interaction, $F\ (3,90) = 1.25$; no significant main effect for location, $F\ (1,90) = 3.33$, $p = .07$; but a significant table effect, $F\ (3,90) = 3.11$. Bonferroni pairwise comparisons indicated that subjects in the visual table , no schema groups used a significantly longer time on the posttest than subjects in the visual table, schema groups. Subjects in the other groups who received the schema also used less time than the no schema groups, but the differences were not statistically significant.

Aptitude x Treatment Interactions

The following hypothesis was of major concern relative to aptitude x treatment interactions:

There will be a differential relationship between criterion performance and aptitude of subjects as measured by the vocabulary, associative memory, science knowledge, and fluid ability measures.

Aptitude x Table x Location

Since both type of table and location of table were varied in the study, possible three-way interactions between

treatment conditions and student aptitudes were investigated. A regression solution for a two-way analysis of covariance was used to detect possible interactions. The possibility of interactions was evaluated by comparing the regression slopes for each treatment condition. An aptitude x treatment interaction existed if the regression lines were significantly nonparallel. Analyses were conducted using the forced choice items, the constructed answer items, and the total posttest.

Possible three-way interactions were investigated using the 14 forced choice items on the posttest as the dependent variable. No significant interactions were found for science knowledge, $F(3,82) = .73$; associative memory, $F(3,82) = .69$; or hidden figures, $F(3,82) = .65$. A marginally significant interaction was detected for vocabulary, $F(3,82) = 2.56$, $p = .06$. The summary statistics for this vocabulary x table x location interaction appear in Table 9.

Possible three-way interactions were also investigated using the 14 constructed answer items on the posttest as the dependent variable. No significant interactions were found for science knowledge, $F(3,82) = .47$; associative memory, $F(3,82) = 1.28$; or hidden figures, $F(3,82) = 1.18$. A three-way interaction was detected for vocabulary, $F(3,82) = 4.10$. The summary statistics for the vocabulary x table x location interaction appear in Table 9.

Finally, three-way interactions were investigated using the total posttest as the dependent variable. As with the

Table 9
F Table for Testing Aptitude x Table x Location Interactions

Source	df	SS	MS	F
		Forced choice items		
Vocabulary x table x location	3	42.50	14.17	2.56
Residual	82	454.52	5.54	
Total	97	586.82		
		Constructed answer items		
Vocabulary x table x location	3	75.54	25.18	4.10*
Residual	82	503.27	6.14	
Total	97	682.69		
		Total posttest		
Vocabulary x table x location	3	206.06	68.67	3.64*
Residual	82	1545.70	18.85	
Total	97	2040.49		

$*p<.05$.

previous two sets of analyses, no significant interactions were found for science knowledge, $F\ (3,82) = .06$; associative memory, $F\ (3,82) = 1.11$; or hidden figures, $F\ (3,82) = 1.01$. However, a three-way interaction was detected for vocabulary, $F\ (3,82) = 3.64$. The summary statistics for this interaction appear in Table 9.

The existence of three-way interactions for vocabulary suggested further analyses. Two-way interactions for vocabulary x table holding location constant and vocabulary x location holding table constant were examined.

Location Constant

When the periodic table was attached to the back of the instructional materials, no vocabulary x table interactions were found for forced choice items, $F\ (3,44) = 2.15$; constructed answer items, $F\ (3,44) = 2.14$; or total posttest, $F\ (3,44) = 2.40$. Analysis for interactions when the periodic table was not attached to the instructional materials revealed no significant vocabulary x table interactions for forced choice items, $F\ (3,38) = .86$; for constructed answer items, $F\ (3,38) = 2.24$; or for the total posttest, $F\ (3,38) = 1.42$.

Table Constant

Additional analyses were performed to determine if interactions existed between the two locations that the table appeared in. For the traditional periodic table, no significant vocabulary x location interactions were detected for

forced choice items, $F(1,20) = 2.65$; for constructed answer items, $F(1,20) = .25$; or for the total posttest, $F(1,20) = 1.48$.

For the periodic table modified by the addition of numerical information, the vocabulary x location interaction for forced choice items approached significance, $F(1,22) = 3.81$. In addition, significant interactions were detected for constructed answer items, $F(1,22) = 5.63$, and for the total posttest, $F(1,22) = 5.64$. In all cases, the table not attached to the instructional materials produced a regression line with negative slope, while the attached table produced a line with positive slope. The interactions for constructed answer items and total posttest are represented in Figures 1 and 2 respectively. Slopes and intercepts for the three dependent measures are summarized in Table 10.

The opposite trend in regression slopes was detected for the table with added visual information. Although no significant vocabulary x location interaction was detected for forced choice items, $F(1,18) = .71$, a significant interaction was found for constructed answer items, $F(1,18) = 5.84$. The attached table location produced a regression line with negative slope while the nonattached table produced a positive slope (Figure 3). Finally, the interaction for the total posttest approached significance, $F(1,18) = 3.28$. Slopes and intercepts for each of the dependent variables are summarized in Table 10.

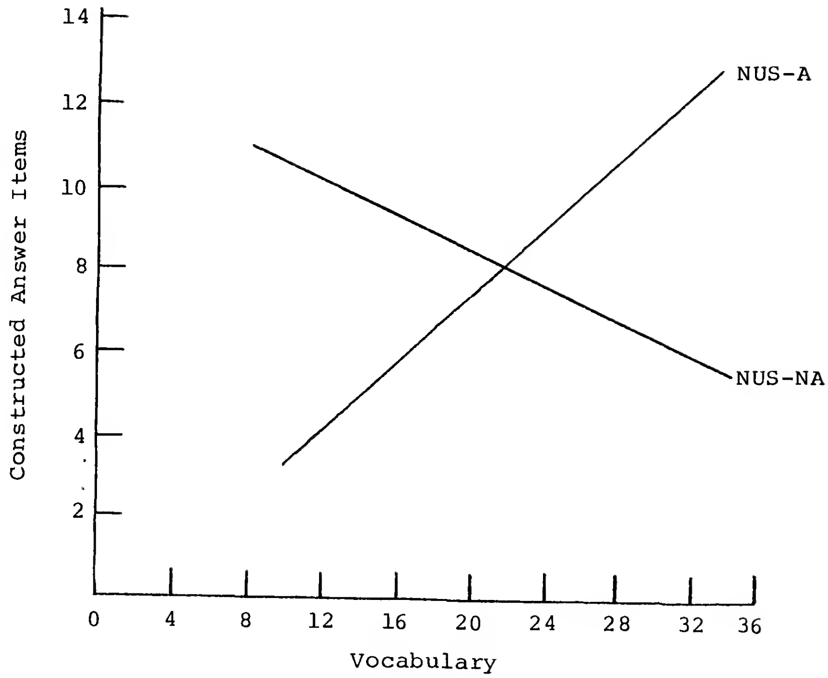


Figure 1. Interaction of vocabulary with constructed answer items for numerical tables at school N.

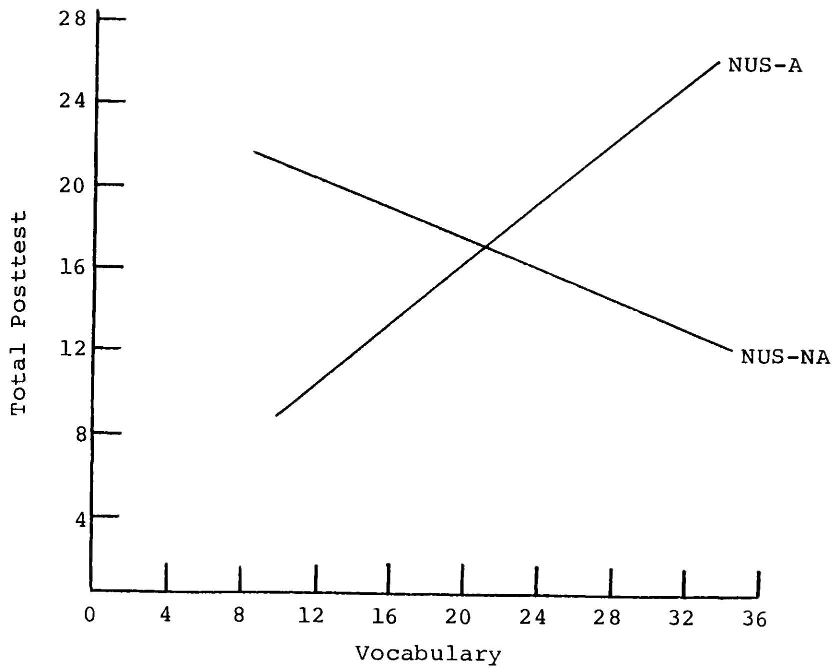


Figure 2. Interaction of vocabulary with total posttest for numerical tables at school N.

Table 10
Intercepts and Slopes for Regression Lines

Treatment[a]	Table attached		Table not attached		
	Intercept	Slope	Intercept	Slope	F
		Forced choice items			
NUS	3.05	.30	12.21	-.14	3.81
VS	12.56	-.15	10.14	.06	.71
		Constructed answer items			
NUS	-1.49	.46	12.16	-.19	5.63*
VS	14.01	-.23	.06	.41	5.84*
		Total posttest			
NUS	1.56	.76	24.37	-.33	5.64*
VS	26.59	-.37	10.20	.48	3.28

[a]NUS = table with added numerical data; VS = table with added visual data.
*$p<.05$.

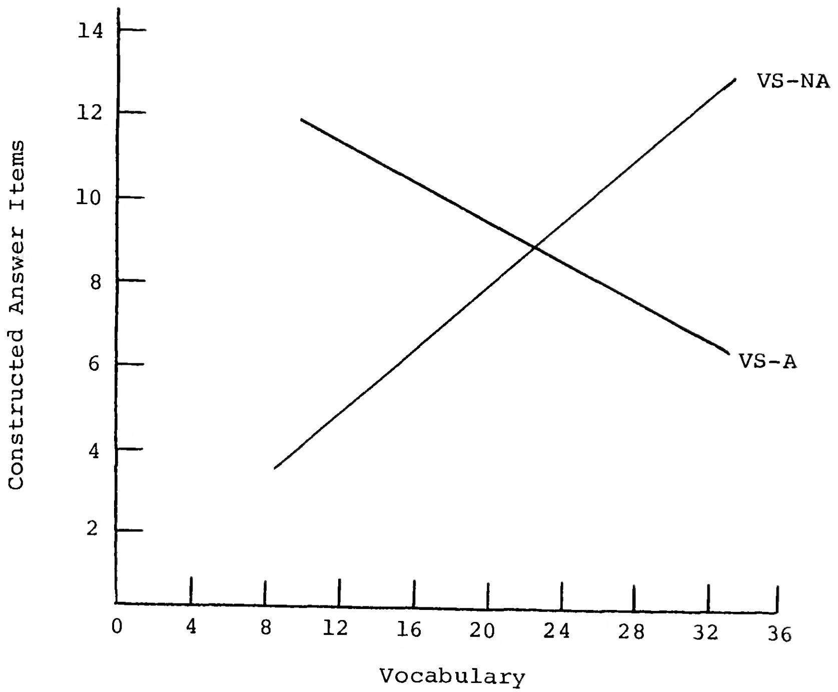


Figure 3. Interaction of vocabulary with constructed answer items for visual tables at school N.

Two-Way Interactions with Other Aptitudes

Since no three-way interactions of aptitude x table x location were found for science knowledge, associative memory, or hidden figures, analyses were performed investigating possible two-way interactions. Aptitude x table and aptitude x location interactions were examined using forced choice items, constructed answer items, and total posttest as the dependent measures. The following 18 combinations of independent and dependent variables were used to investigate aptitude x treatment interactions:

1. Science knowledge x table for forced choice items
2. Science knowledge x table for constructed answer items
3. Science knowledge x table for total posttest
4. Associative memory x table for forced choice items
5. Associative memory x table for constructed answer items
6. Associative memory x table for total posttest
7. Hidden figures x table for forced choice items
8. Hidden figures x table for constructed answer items
9. Hidden figures x table for total posttest
10. Science knowledge x location for forced choice items
11. Science knowledge x location for constructed answer items
12. Science knowledge x location for total posttest

13. Associative memory x location for forced choice items
14. Associative memory x location for constructed answer items
15. Associative memory x location for total posttest
16. Hidden figures x location for forced choice items
17. Hidden figures x location for constructed answer items
18. Hidden figures x location for total posttest

In none of the above cases was a significant interaction detected. The F values for aptitude x table and aptitude x location interactions appear in Tables 11 and 12 respectively.

Variables—School O

Instructional materials consisted of seven to eight pages of written materials accompanying a periodic table. Six of the eight groups also received a two-page schema. Data were collected for each group on the number of text questions answered correctly, the number of schema questions answered correctly, and the time spent reading the instructional materials. Cell frequencies, means, and standard deviations for these variables are reported in Table 13.

Scores were also recorded for each subject on the posttest comprised of 28 items. This score was subsequently subdivided into a score for the forced choice items and a score for the constructed answer items. In addition, the length of

Table 11
F Values for Aptitude x Table Interactions Between Aptitudes and Criteria Measures for School N

Interaction	df	F
Forced choice items		
Science knowledge x table	3,85	.25
Associative memory x table	3,85	.32
Hidden figures x table	3,85	.86
Constructed answer items		
Science knowledge x table	3,85	.19
Associative memory x table	3,85	1.71
Hidden figures x table	3,85	.48
Total posttest		
Science knowledge x table	3,85	.03
Associative memory x table	3,85	.64
Hidden figures x table	3,85	.37

Table 12
F Values for Aptitude x Location Interactions
Between Aptitudes and Criteria Measures for School N

Interaction	df	F
Forced choice items		
Science knowledge x location	1,85	.26
Associative memory x location	1,85	.38
Hidden figures x location	1,85	.27
Constructed answer items		
Science knowledge x location	1,85	.25
Associative memory x location	1,85	.16
Hidden figures x location	1,85	.00
Total posttest		
Science knowledge x location	1,85	.32
Associative memory x location	1,85	.30
Hidden figures x location	1,85	.07

Table 13
Instructional Materials Data for School O

Treatment[a]	Text questions			Schema questions			Reading time		
	n	Mean	SD	n	Mean	SD	n	Mean	SD
TS-A	8	8.75	.89	7	5.00	1.41	8	37.25	6.71
TS-NA	10	9.50	.85	8	5.25	1.16	10	35.20	8.23
NUS-A	8	8.88	1.36	8	4.50	1.20	8	34.00	5.98
NUS-NA	7	9.57	.79	5	5.00	.71	7	36.57	9.16
VS-A	7	9.43	.79	7	5.57	.79	7	31.71	6.02
VS-NA	7	9.00	1.15	5	4.80	1.64	7	34.86	7.60
V-A	7	9.71	.76	--	--	--	7	33.29	6.16
V-NA	8	9.50	.76	--	--	--	8	29.75	6.09

[a]TS-A = traditional table, attached, schema present; TS-NA = traditional table, not attached, schema present; NUS-A = table with added numerical data, attached, schema present; NUS-NA = table with added numerical data, not attached, schema present; VS-A = table with added visual data, attached, schema present; VS-NA = table with added visual data, not attached, schema present; V-A = table with added visual data, attached, no schema; V-NA = table with added visual data, not attached, no schema.

time students used to complete the posttest was recorded. Descriptive statistics for these variables are reported in Table 14.

Finally, data for each subject were collected on measures of vocabulary, science knowledge, associative memory, and hidden figures. Cell frequencies, means, and standard deviations are reported in Table 15.

Instructional Treatment Main Effects

The following research hypotheses were of major concern relative to instructional treatment main effects:

1. Subjects receiving periodic tables modified by the addition of numerical or visual information will perform significantly better on the criterion measure than subjects receiving the traditional periodic table.
2. Subjects receiving periodic tables not attached to the written materials will perform significantly better on the criterion measure than subjects receiving periodic tables attached to the instructional materials.
3. Subjects receiving a two-page schema containing a network of relationships designed to help students process the chemistry topics contained in the written materials will perform significantly better on the criterion measure than subjects not receiving a schema.

Table 14
Posttest Data for School O

Treatment[a]	Forced choice			Constructed answer			Total posttest			Test time		
	n	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD
TS-A	8	9.00	2.07	8	8.38	2.92	8	17.38	4.75	8	20.50	5.40
TS-NA	10	10.20	2.70	10	10.10	2.18	10	20.30	4.08	10	22.00	4.06
NUS-A	8	8.25	1.91	8	7.50	2.20	8	15.75	3.99	8	18.75	3.06
NUS-NA	7	9.71	1.38	7	10.14	2.48	7	20.00	3.74	7	20.86	4.26
VS-A	7	10.29	2.29	7	10.00	2.38	7	20.29	4.57	7	19.71	3.35
VS-NA	7	9.71	2.56	7	9.71	2.43	7	19.43	4.86	7	20.57	4.43
V-A	7	9.71	3.04	7	9.29	2.81	7	19.00	5.48	7	21.14	2.91
V-NA	8	9.50	2.20	8	9.25	1.91	8	18.75	3.88	8	21.38	2.39

[a]TS-A = traditional table, attached, schema present; TS-NA = traditional table, not attached, schema present; NUS-A = table with added numerical data, attached, schema present; NUS-NA = table with added numerical data, not attached, schema present; VS-A = table with added visual data, attached, schema present; VS-NA = table with added visual data, not attached, schema present; V-A = table with added visual data, attached, no schema; V-NA = table with added visual data, not attached, no schema.

Table 15
Aptitude Data for School O

Treatment[a]	Science knowledge			Vocabulary			Associative memory			Hidden figures		
	n	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD
TS-A	8	13.57	2.76	8	18.86	4.98	8	18.50	6.07	8	4.88	2.70
TS-NA	10	13.30	2.31	10	18.00	3.92	9	20.44	5.98	9	4.67	2.12
NUS-A	8	13.43	1.51	8	19.43	3.21	8	18.25	5.78	8	4.13	1.89
NUS-NA	7	12.71	2.06	7	18.86	2.34	7	18.86	5.30	7	4.43	2.82
VS-A	7	14.14	2.34	7	21.14	4.41	7	16.86	5.81	7	4.00	2.24
VS-NA	7	14.33	2.42	7	21.00	5.18	7	21.67	7.55	7	4.50	2.51
V-A	7	14.00	2.00	7	17.71	4.92	6	20.25	6.18	6	7.50	3.00
V-NA	8	14.29	1.70	8	19.86	5.84	8	17.50	6.50	8	5.13	3.04

[a]TS-A = traditional table, attached, schema present; TS-NA = traditional table, not attached, schema present; NUS-A = table with added numerical data, attached, schema present; NUS-NA = table with added numerical data, not attached, schema present; VS-A = table with added visual data, attached, schema present; VS-NA = table with added visual data, not attached, schema present; V-A = table with added visual data, attached, no schema; V-NA = table with added visual data, not attached, no schema.

In order to investigate main effects for type of periodic table, location of table, and the presence of a schema, a regression equation was used containing both table and location as components of the regression model. A summary of F values for all three dependent measures is provided in Table 16.

No significant differences were found for type of periodic table, location of table, or the presence of a schema for any of the dependent measures. Thus the hypotheses were not supported by the data.

Text Questions, Reading Time, and Test Time

Analyses of variance were also performed using inserted text questions, reading time with the instructional materials, and posttest time as the dependent variables. Summary statistics for all three analyses appear in Table 17.

Text Questions

Subjects in all eight experimental groups received 10 questions within their instructional materials. The purpose of these questions was to assure that subjects used all the instructional materials provided. Subjects were required to use the accompanying periodic table to answer the inserted questions. Results from the analysis of variance indicated no significant table x location interaction, $F\ (3,54) = 1.61$; no significant location effect, $F\ (3,54) = .70$; and no significant table effect, $F\ (3,54) = .80$. Thus it appeared

Table 16
Summary Table of Dependent Variable Main Effects for School O

Source	df	SS	MS	F
		Forced choice items		
Table	3	8.36	2.79	.52
Location	1	4.15	4.15	.78
Residual	57	304.38	5.34	
Total	61	317.35		
		Constructed answer items		
Table	3	8.61	2.87	.48
Location	1	17.45	17.45	2.94
Residual	57	338.13	5.93	
Total	61	364.77		
		Total posttest		
Table	3	31.18	10.39	.53
Location	1	40.39	40.39	2.05
Residual	57	1124.04	19.72	
Total	61	1197.69		

Table 17
Summary Table for Analysis of Variance for School O

Source	df	SS	MS	F
		Test questions		
Table	3	2.13	.71	.80
Location	1	.62	.62	.70
Table x location	3	4.27	1.42	1.61
Residual	54	47.73	.88	
Total	61	54.77		
		Reading time		
Table	3	209.63	69.88	1.38
Location	1	.02	.02	.00
Table x location	3	124.42	41.47	.82
Residual	54	2730.03	50.56	
Total	61	3064.21		
		Test time		
Table	3	26.24	8.75	.59
Location	1	21.08	21.08	1.42
Table x location	3	7.38	2.46	.17
Residual	54	802.23	14.86	
Total	61	861.89		

that all subjects could answer the inserted questions regardless of the type of table present with the instructional materials.

Reading Time

It was anticipated that subjects not receiving the two-page schema would spend less time with the instructional materials. An analysis of variance revealed no significant differences between groups (Table 17).

Test Time

An analysis of variance was performed on test time. Results indicated that no significant differences existed between groups (Table 17).

Aptitude x Treatment Interactions

The following hypothesis was of major concern relative to aptitude x treatment interactions:

There will be a differential relationship between criterion performance and aptitudes of subjects as measured by the vocabulary, associative memory, science knowledge, and fluid ability measures.

Aptitude x Table x Location

Since both type of table and location of table were varied in the study, possible three-way interactions between treatment conditions and student aptitudes were investigated. A regression solution for a two-way analysis

of covariance was used to detect possible interactions. The existence of interactions was evaluated by comparing the regression slopes for each treatment condition. An aptitude x treatment interaction existed if the regression lines were significantly nonparallel. Analyses were conducted using scores on the forced choice items, the constructed answer items, and the total posttest.

Three-way interactions were investigated using the 14 forced choice items on the posttest as the dependent measure. No significant interactions were found for science knowledge, $F(3,46) = .81$; associative memory, $F(3,44) = .24$; vocabulary, $F(3,46) = .10$; or hidden figures, $F(3,44) = .76$.

Possible three-way interactions were also investigated using the 14 constructed answer items on the posttest as the dependent variable. No significant interactions were detected for science knowledge, $F(3,46) = .96$; associative memory, $F(3,44) = .61$; vocabulary, $F(3,46) = 1.22$; or hidden figures, $F(3,44) = 1.82$.

Finally, three-way interactions were investigated using the total posttest as the dependent variable. As with the previous two sets of analyses, no significant interactions were detected for science knowledge, $F(3,46) = .96$; associative memory, $F(3,44) = .29$; vocabulary, $F(3,46) = .57$; or hidden figures, $F(3,44) = 1.44$.

Two-Way Interactions

Since no three-way interactions of aptitude x table x location were detected for any of the aptitude variables, analyses were performed investigating possible two-way interactions. Aptitude x table and aptitude x location interactions were examined using forced choice items, constructed answer items, and the total posttest as the dependent measures. The following 24 combinations of independent and dependent variables were used to investigate aptitude x treatment interactions:

1. Science knowledge x table for forced choice items
2. Science knowledge x table for constructed answer items
3. Science knowledge x table for total posttest
4. Vocabulary x table for forced choice items
5. Vocabulary x table for constructed answer items
6. Vocabulary x table for total posttest
7. Associative memory x table for forced choice items
8. Associative memory x table for constructed answer items
9. Associative memory x table for total posttest
10. Hidden figures x table for forced choice items
11. Hidden figures x table for constructed answer items
12. Hidden figures x table for total posttest
13. Science knowledge x location for forced choice items

14. Science knowledge x location for constructed answer items
15. Science knowledge x location for total posttest
16. Vocabulary x location for forced choice items
17. Vocabulary x location for constructed answer items
18. Vocabulary x location for total posttest
19. Associative memory x location for forced choice items
20. Associative memory x location for constructed answer items
21. Associative memory x location for total posttest
22. Hidden figures x location for forced choice items
23. Hidden figures x location for constructed answer items
24. Hidden figures x location for total posttest

For science knowledge, associative memory, and hidden figures no significant interactions were detected. The F values for aptitude x table and aptitude x location interactions appear in Tables 18 and 19 respectively.

For vocabulary, however, a significant vocabulary x table interaction, $F(3,49) = 3.22$, and a significant vocabulary x location interaction, $F(1,49) = 4.46$, were detected for forced choice items. In addition, the vocabulary x

Table 18
F Values for Aptitude x Table Interactions Between Aptitudes and Criteria Measures for School O

Interaction	df	F
Forced choice items		
Science knowledge x table	3,49	.88
Associative memory x table	3,47	1.88
Hidden figures x table	3,47	.21
Constructed answer items		
Science knowledge x table	3,49	.02
Associative memory x table	3,47	.52
Hidden figures x table	3,47	.07
Total posttest		
Science knowledge x table	3,49	.27
Associative memory x table	3,47	1.11
Hidden figures x table	3,47	.07

Table 19
F Values for Aptitude x Location Interactions
Between Aptitudes and Criteria Measures for School O

Interaction	df	F
Forced choice items		
Science knowledge x location	1,49	.02
Associative memory x location	1,47	.66
Hidden figures x location	1,47	.05
Constructed answer items		
Science knowledge x location	1,49	.00
Associative memory x location	1,47	1.63
Hidden figures x location	1,47	.00
Total posttest		
Science knowledge x location	1,49	.00
Associative memory x location	1,47	1.16
Hidden figures x location	1,47	.00

table and vocabulary x location interactions for the total posttest approached significance. The F tables for vocabulary x table and vocabulary x location interactions for all three dependent measures are summarized in Table 20. The slopes and intercepts for the regression lines representing each treatment appear in Table 21. Finally, the significant vocabulary x table and vocabulary x location interactions for the forced choice items appear in Figures 4, 5, and 6.

Follow-up Bonferroni $\underline{t}$ tests on the vocabulary x table regression slopes failed to detect the nature of the interaction. However, from the confidence intervals produced, it appeared that the vocabulary x traditional table regression slope was negative and significantly different from the slopes produced by the other three tables. All modified tables had a positive slope and no differences seemed to appear between the groups.

The vocabulary x location interaction indicated that for each type of table the regression line for the nonattached location of the table was flatter. Thus lower ability students benefited more from the nonattached periodic table condition.

Table 20
F Table for Testing Aptitude x Treatment Interactions Between Vocabulary and Criteria Measures for School O

Source	df	SS	MS	F
		Forced choice items		
Vocabulary x table	3	41.95	13.98	3.22*
Vocabulary x location	1	19.32	19.32	4.46*
Residual	49	212.45	4.34	
Total	61	317.35		
		Constructed answer items		
Vocabulary x table	3	19.24	6.41	1.23
Vocabulary x location	1	7.28	7.28	1.40
Residual	49	255.21	5.21	
Total	61	364.77		
		Total posttest		
Vocabulary x table	3	117.00	39.00	2.41
Vocabulary x location	1	49.67	49.67	3.11
Residual	49	781.86	15.96	
Total	61	1197.69		

*p<.05.

Table 21
Intercepts and Slopes for Regression Lines

Treatment[a]	Forced choice items		Total posttest	
	Intercept	Slope	Intercept	Slope
TS-A	9.25	-.01	16.28	.06
TS-NA	15.38	-.29	27.24	-.39
NUS-A	-.34	.44	-2.10	.92
NUS-NA	6.54	.17	10.96	.48
VS-A	.80	.45	3.63	.79
VS-NA	6.20	.17	12.41	.35
V-A	2.56	.40	5.82	.74
V-NA	7.04	.13	12.97	.30

[a]TS-A = traditional table, attached, schema present; TS-NA = traditional table, not attached, schema present; NUS-A = table with added numerical data, attached, schema present; NUS-NA = table with added numerical data, not attached, schema present; VS-A = table with added visual data, attached, schema present; VS-NA = table with added visual data, not attached, schema present; V-A = table with added visual data, attached, no schema; V-NA = table with added visual data, not attached, no schema.

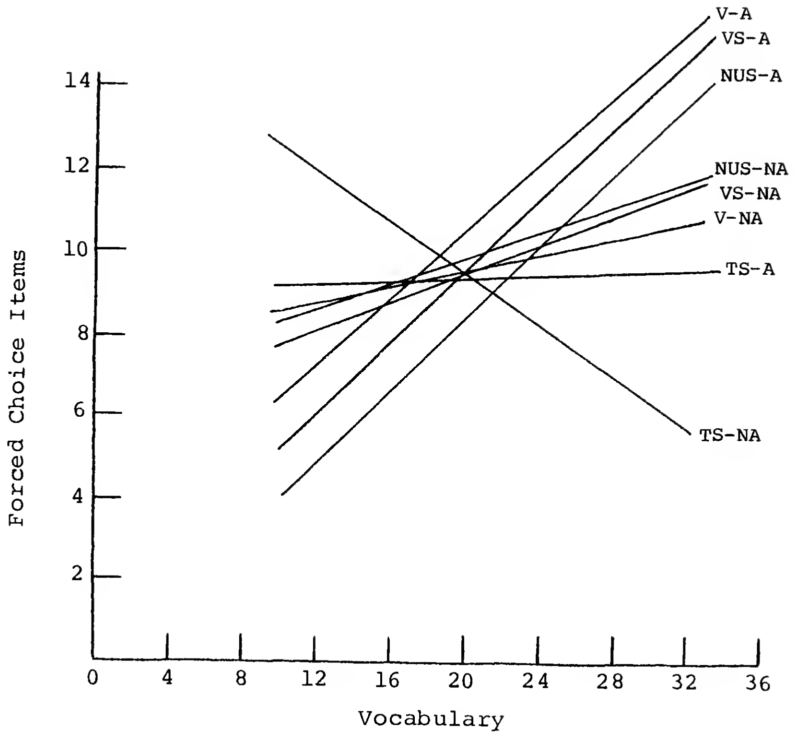


Figure 4. Interaction of vocabulary with forced choice items at school O.

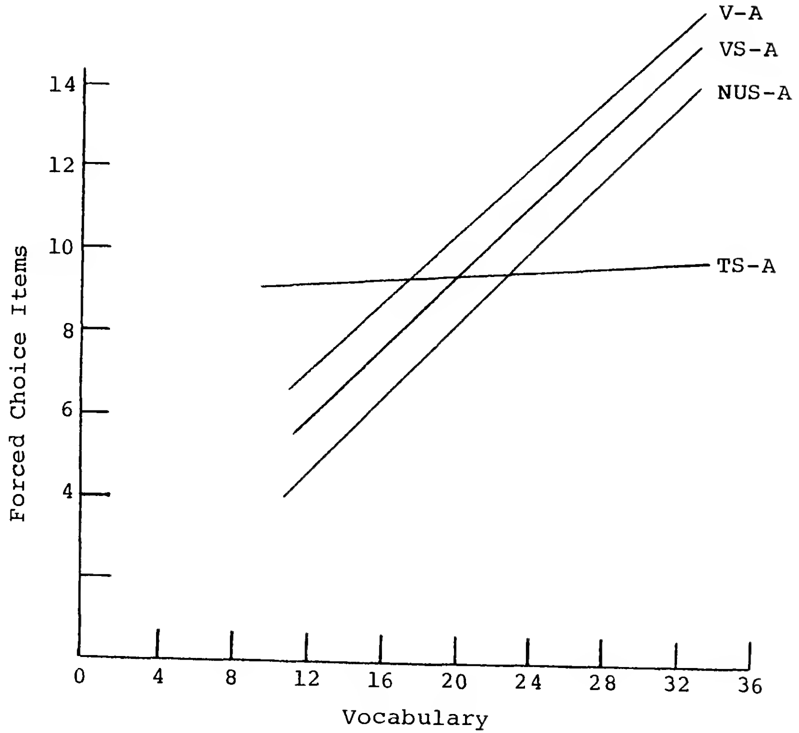


Figure 5. Interaction of vocabulary with forced choice items for attached tables at school O.

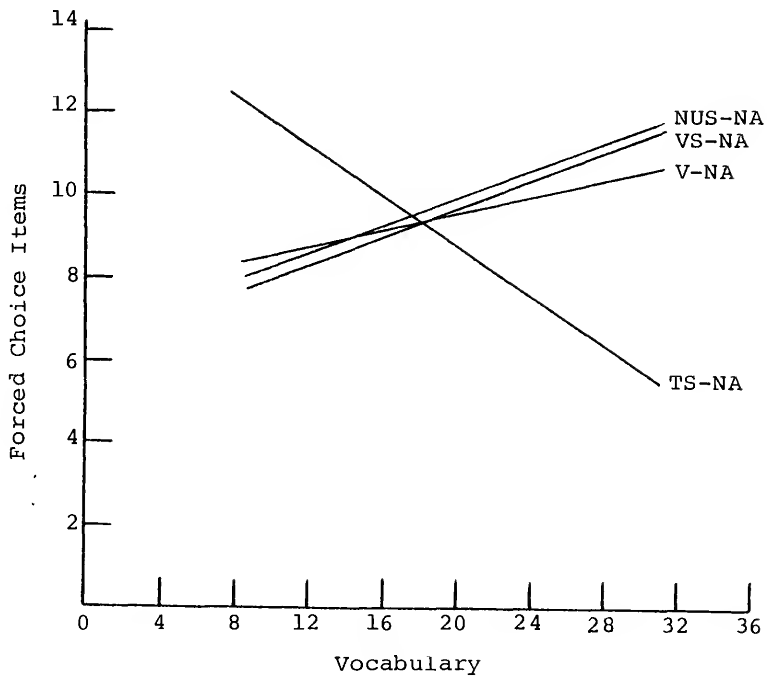


Figure 6. Interaction of vocabulary with forced choice items for nonattached tables at school O.

CHAPTER V
DISCUSSION AND IMPLICATIONS

This study sought to examine the effects of modifications to the traditional periodic table. The determination of which variations in the periodic table appeared best for particular types of students was also of interest. Some general premises basic to the study included the following:

1. Because the periodic table contains information presented throughout chemistry textbooks, it can be considered a condensed analog of the written materials.
2. The internal processing activities which contribute to the encoding of information can be influenced by the nature of the physical stimulus such that the structure and organization of the stimulus can reduce the processing burden placed on the learner.
3. A table modified by the addition of information may produce a more complete content structure which may help students process the data and relationships from the table.
4. The effectiveness of different versions of the periodic table will vary from individual to individual with differences being correlated with learner aptitudes.

Instructional Treatment Main Effects

Modification of the Periodic Table

The first hypothesis tested was

1. Subjects receiving periodic tables modified by the addition of numerical or visual information will perform significantly better on the criterion measure than subjects receiving the traditional periodic table.

In order to investigate main effects for type of table, location of table, and the presence of a schema, a regression equation was used containing both table and location as components in the regression model. A significant F statistic indicated differences between treatment conditions. Bonferroni $\underline{t}$ tests were used to detect the nature of any differences.

When the dependent variable was the forced choice portion of the posttest, a significant table effect was detected for subjects having little prior experience with the periodic table. In addition, a marginally significant table effect was found for the total posttest. Follow-up analyses suggested that subjects who used the periodic table with added visual information performed better than subjects who used either the traditional table or the table modified with added numerical information. No differences were detected between the latter two tables.

As anticipated, the periodic table modified with visual information proved to be superior to the traditional periodic table. When compared to the traditional table, the information presented on the visual table provided a more complete content structure for the user of the table. Both the added information and the visual mode of presentation may have helped students transfer content relationships from the written materials to the table and vice versa, much as in Gentner's (1980) research on structure mapping between content domains. In addition, color and shading were used on the visual table to group related elements. These modifications may have served to direct students' attention to specific properties of elements as well as to help students organize parts of the complex display, thus reducing the processing burden. These functions are consistent with Chute's (1979) conclusion that color's importance in other visuals rested primarily on the degree to which color facilitated for the learner the organizing and structuring of the presented stimuli.

The table with added visual information was also superior to the table with added numerical information. Because many of the properties of elements depend upon atomic structure, the relative sizes of the atoms were included on the modified tables. On the visual table the relative size was designated by a semicircle representing the outer shell of the atom. Learners should quickly see this

semicircle when viewing the table. This focusing of attention may then help students perceive the importance of atomic structure and the properties derived from it. Students who viewed the table with added numerical information were presented with a numerical representation of atomic size. These students would have to distinguish this number from the other numerical data presented within each block, translate the number into a view of the atom, compare this view with views of other elements' atoms derived the same way, and then derive the properties from atomic structure. Consequently, the greater processing requirements of the numerical table as well as the relatively short exposure to the materials may have resulted in the superiority of the table with added visual data.

Finally, no differences were detected between the traditional periodic table and the table with added numerical information, which supports Dwyer's (1972) contention that the mere addition of information to a visual does not automatically enhance learning from it. Apparently the added numerical information did not function to help students structure and process the relationships from the table. Because students had little prior experience with the table, the short treatment exposure may have limited the amount of processing which occurred, thus minimizing the effects of the added information. Perhaps with longer instructional periods differences between these tables may develop.

For subjects who had already been taught the periodic table no significant main effects for table were detected. This result is not surprising in light of Larkin's (1980) work with expert-novice learning. Subjects who already experienced and used the table might be considered equivalent to "experts." Consequently, they would have developed a network of relationships between the content contained on the table and content derived from it. Modifications designed to help students develop such a structure would not prove beneficial.

In summary, the data partially supported hypothesis one. Although results depended upon prior experience with the periodic table, some subjects did appear to benefit from modifications to the table. However, the type of modification was crucial. Subjects performed better when modifications such as visual representations of atoms, color, and shading were used. These modifications seemed to help students organize and process the relationships between chemistry topics depicted on the periodic table and referred to in the literature.

Location of the Table

The second hypothesis tested was

2. Subjects receiving periodic tables not attached to the written materials will perform significantly better on the criterion measure than subjects receiving periodic tables attached to the instructional materials.

Inspection of F statistics failed to support this hypothesis. No significant main effect for location was found at either school, although trends suggested that the table not attached to the instructional materials was the superior location.

Students often perceive the written material explaining the periodic table as new and complex. Therefore, in order to apply the written material to the table, students must constantly view the table. A table located at the back of a textbook places a major emphasis on a student's short-term memory. Students must read the content, hold the content in memory, turn to the table, retrieve the content, apply the content to the table, store information obtained from the table, and refer back to the text. This complicated procedure can lead to confusion and gaps at any one point. By providing a table alongside the written materials, educators could reduce the memory burden, which should facilitate processing of the information. Hence it was anticipated that subjects using a periodic table alongside the written materials would learn more than subjects required to constantly turn to the back of the materials in order to use the table. Such a result would have implications for textbook publishers who are deciding whether or not to include removable inserts in texts.

Although no differences were detected in this study, generalizations from this result should be limited.

Subjects used the instructional materials for only one day. Because all subjects were instructed to study the periodic table carefully, they may have turned to the table even if they normally would not have. Another possibility is that subjects did not take advantage of the fact that the table was not attached. A good deal of literature suggests that when verbal and visual information are redundant, subjects will ignore the visual. Additional investigations with subjects over longer time periods are warranted.

In summary, data did not support hypothesis two. The location of the periodic table did not appear to be a significant factor.

<u>Presence of Schema</u>

The third hypothesis tested was

3. Subjects receiving a two-page schema containing a network of relationships designed to help students process the chemistry topics contained in the written materials will perform significantly better on the criterion measure than subjects not receiving a schema.

This hypothesis was tested by comparing the mean of the groups receiving the visual table with schema to the mean of the groups receiving only the visual table. Results indicated no significant main effect for subjects at either school.

The purpose of the two-page schema was to organize and display the network of relationships that existed between the chemistry topics explained in the written materials. From an information processing point of view the schema should function to help students organize the relationships between content topics. Because the schema condenses many pages of explanation into a single display, all relevant information is in the learner's view at one time. Learners can then follow the flow pattern on the schema, reverse their scanning, rehearse connections between topics, and concentrate on specific areas of the schema. All of these processes should help students construct a network of science knowledge to be used with the periodic table. Whereas the topics explained in the instructional materials are generally separated by many pages in traditional chemistry textbooks, the topics were condensed here into seven pages of instructional materials. This physical closeness may have facilitated the student's task of relating topics, thus making the schema less effective.

Alternatively, the absence of main effects could suggest that subjects either ignored the schema or were not capable of processing the information contained in the schema. Although the schema contained the same subject matter as the written materials, subjects may not have understood what to do with the schema. Because learners may not have the experience perceiving the match between a schema

and corresponding written materials, it is not surprising that subjects have not successfully processed displays such as schema (Carpenter et al., 1978; Vernon, 1950). However, this effort took the above into account and required students to answer questions about the schema. The purpose of these questions was to force students to search for links between content topics. The success of adding questions after the schema appeared minimal because the students spent little time interacting with the schema.

Modifications to the schema used in this study may be worthy of investigation. Additional research designed to focus a student's attention to specific portions of the schema while he reads the written materials would be appropriate. Finally, students may benefit from instruction desinged to help them abstract relationships from non-textual displays.

In summary, the hypothesis that schema designed to help students form a network of relationships would enhance their learning was not supported. Subjects were either able to use the written materials to construct a series of relationships, thus making the schema unnecessary, or they did not know how to process the schema effectively.

Aptitude x Treatment Interactions

The fourth hypothesis tested was

4. There will be a differential relationship between criterion performance and aptitudes of subjects

as measured by the vocabulary, associative memory, science knowledge, and fluid ability measures.

This hypothesis was tested by comparing the regression slopes for each treatment condition. An aptitude x treatment interaction existed if the regression lines were significantly nonparallel. Significant interactions were detected at both schools when vocabulary was the aptitude. No interactions were found for science knowledge, associative memory, or hidden figures.

Significant two-way interactions were detected for subjects who were taught the periodic table just prior to the experimental study. Significant vocabulary x table and significant vocabulary x location interactions were detected using the forced choice items as the dependent variable. In addition, vocabulary x table and vocabulary x location interactions for the total posttest approached significance. Although follow-up tests failed to detect the nature of the vocabulary x table interaction, confidence interval data suggested that the vocabulary x traditional table regression slope was negative and significantly different from the positive slopes produced by the other three treatment conditions. Hence, lower ability students tended to benefit from the traditional table. Perhaps the modification of the table through added numerical or visual information tended to make the modified tables more complicated for low ability subjects. Zeaman and House (1963) found that lower ability

subjects were generally lacking in attentional and discriminating skills. Because more information is presented on the modified tables, lower ability subjects may have more difficulty distinguishing which piece of data is appropriate in specific instances. Moreover, since the subjects had already received instruction using the traditional periodic table, the introduction of innovative materials could have an interference effect. Consequently, the lower ability student would process the less complex, traditional table more effectively (Allen, 1975).

Conversely, higher ability students are more capable of taking advantage of the additional information. These students already have a network of relationships that is made more complete with the addition of information to the table. The students already possess the strategies needed to organize, synthesize, and relate the data from more complex displays.

The vocabulary x location interaction indicated that for each type of table the regression line for the non-attached location of the periodic table was flatter. Thus, individuals lower in verbal comprehension ability benefited from having the table alongside the written materials. The proximity of the table to the materials would reduce the information processing burden imposed by separating the table and materials. Lower ability students would more likely transfer relationships from the written materials to the

table if both are viewed simultaneously. Higher ability students would be able to perform such processes regardless of the table location.

A more complex vocabulary x table x location interaction was found with subjects who had little prior experience with the periodic table. Additional analyses revealed the nature of the interaction. For the periodic table modified with added numerical information, the vocabulary x location interaction was significant for constructed answer items and the total posttest, and approached significance for the forced choice items. In all cases the nonattached table location was better for subjects scoring low in vocabulary, while the attached table was better for those scoring higher in vocabulary.

One possible interpretation is that subjects low in verbal comprehension benefited from the availability to search the periodic table at the same time they read about the added content. This would be especially true with added numerical information since no relationships appear to exist between each piece of information. Added exposure may have reduced the difficulty subjects generally have discriminating between pieces of data.

The opposite trend in regression slopes was detected for the table with added visual information and the presence of the schema in the instructional materials. Subjects scoring high in verbal comprehension performed better when the table was not attached and the constructed answer items was the dependent variable. A marginally significant

interaction was detected for the total posttest, while no interaction existed for the forced choice items.

When the table was modified by adding visual data, a system of relationships between chemistry topics could be derived. Lower ability students might find the system too complex to process. Higher ability students, on the other hand, do better when challenged and left on their own. As more information appears related on the table, higher ability students can modify their own information networks. Having the visual table beside the written materials may provide these higher ability students with more opportunities to restructure the information.

An alternative explanation for both three-way interactions was their chance occurrence. Due to the large number of interactions tested and the fact that no interaction was found for the visual table without schema this alternative must be considered.

While a large number of two-way interactions were tested, significant interactions were found only for vocabulary. This result is consistent with previous aptitude x treatment research (Cronbach & Snow, 1977) in which general ability, of which verbal comprehension is an index, has repeatedly entered into interactions when meaningful instructional material was used. No interactions were detected for science knowledge, associative memory, or hidden figures. The low reliability coefficient calculated

for the science knowledge pretest would have reduced the chances of any interactions being detected. Future research might focus on developing a more reliable science measure, using previous science course grades, or using a standardized science achievement score for use in aptitude x treatment research.

Other factors which may have lead to low power in detecting any interactions were the number of subjects in each treatment condition and the time span of the study. Cronbach and Snow (1977) suggested a minimum of 100 subjects per treatment and treatments that lasted several days. Such designs are more powerful and could be used to detect small differences. However, in this initial study investigating modifications to the periodic table, these suggestions were not deemed practical.

In summary, the evidence collected partially supported hypothesis four. Although no interactions were detected for science knowledge, associative memory, or hidden figures, significant interactions were found with vocabulary as the aptitude. Generally speaking, lower ability subjects benefited from the traditional periodic table while higher ability students were better prepared to process additional information on more complex tables. In addition, lower ability students benefited when they were permitted to view the table and corresponding written materials simultaneously. However, these generalizations held

true only for subjects with prior instruction with the periodic table.

Conclusion

Whereas many scientists have assumed that adding information to the periodic table would make it more useful, no research studies were located that investigated students' learning from the table. This study found that the mere addition of information to the table did not guarantee that additional learning would take place from the table. However, if the modified table had color, shading, and visual representations of atoms included on it, then the table was more effective for students with little prior experience with the periodic table. It also appeared that subjects familiar with the periodic table differentially benefited from these modifications. Lower ability students used the traditional table more effectively, while higher ability students used the richer, modified tables better. Lower ability students also seemed to benefit from having the periodic table detached from the written materials. Additional research is needed with subjects of different abilities using modified tables to study different content for longer periods of time.

That the schema did not seem to aid in processing of the tables could be explained in a number of ways. First, the schema was unfamiliar to the leaners; hence they did not know how to use it. It is possible that prior training

on similar analogical models would have made a difference. At the same time, students are not used to spending significant "think" time with instructional materials such as chemistry materials. The short time spent on reviewing these instructional materials seems hardly adequate to perceive, encode, store, and retrieve relevant information. Further research is needed to explore each of the above.

APPENDIX A
INSTRUCTIONAL MATERIALS ACCOMPANYING PERIODIC TABLES: TRADITIONAL PERIODIC TABLE (T), TABLE WITH ADDED NUMERICAL INFORMATION (N), TABLE WITH ADDED VISUAL INFORMATION (V)

Traditional Periodic Table (T)

Please read the following instructions VERY CAREFULLY.

In this packet you have three types of chemistry materials. First you have 7-8 pages of written material describing topics you learn about in chemistry.

Second, you have two 1-page diagrams. The diagrams show how the topics you read relate to each other.

Finally, you have a copy of the periodic table. Since you will read material that refers to the periodic table, BE SURE TO LOOK AT THE PERIODIC TABLE AS YOU READ.

Your job is to read the written material carefully. In addition study carefully the diagrams. Refer to the periodic table as you read the material and study the diagrams. In addition, there are questions in the written materials and after the diagrams. Answer all the questions on the answer sheet provided.

Take as much time as you need on each page, but once you complete a page, turn it over and do not go back to that page. Learn as much as possible. Later, you will take a test covering the material.

Chemistry and the Atom

Atoms are the building blocks of all chemical substances. Atoms consist of two main regions: the center and the space around the center. The nucleus is the name for the dense, center portion of the atom. Two particles, protons and neutrons, make up the nucleus. Protons are particles with a positive charge while neutrons have no charge.

The space around the nucleus is the second region of an atom. Negatively charged particles called electrons spin around the nucleus. The positively charged protons in the nucleus pull the negatively charged electrons towards the nucleus, since oppositely charged particles attract.

An element is a substance consisting of atoms that are alike. Atoms are alike if they all have the same number of protons in the nucleus. Scientists have discovered 103 different chemical elements. Scientists grouped these elements according to their properties and displayed them on charts called periodic charts or periodic tables. You will discover why scientists used the term periodic.

Information About Each Element

Each block on the chart stores information about one element. Within each block you will find three pieces of information; the element's chemical symbol, its atomic mass, and its atomic number. The chemical symbol is a shorthand notation representing the name of the element. The atomic mass is the average mass of the atoms of an element.

Generally you find the atomic mass located below the symbol of the element.

The atomic number indicates the number of positively charged protons in the nucleus. The atomic number is always a whole number since there are no fractions of protons. Typically you find the atomic number located above the symbol of the element.

Usually there are as many electrons spinning around the nucleus as there are protons in the nucleus. So if you know the atomic number, you know both the number of protons in the nucleus and the number of electrons spinning outside the nucleus.

For the element beryllium, Be, the atomic number is 4. Every atom of beryllium has 4 protons in the nucleus and 4 electrons spinning around the nucleus. (1. What is the atomic number of Na and how many electrons does an atom of Na have?)

The element cesium, Cs, has 55 protons in the nucleus and 55 electrons around the nucleus. Fifty-five electrons is a lot. Since all the electrons are negatively charged, they repel each other and spread apart. As the electrons spread apart they move to separate pathways. These pathways are called shells. You indicate shells by giving each shell a number. The first shell is the one closest to the nucleus. The next shell away from the nucleus is the second shell, then the third shell and so on. Shells farther from the

nucleus have larger paths around the nucleus. Furthermore, shells with larger paths have a larger electron capacity than shells closer to the nucleus. The first shell has an electron capacity of 2 electrons. The second shell has a capacity of 8 electrons, the third shell 18, and the fourth shell 32. Eight, 18, and 32 electrons is still a lot. Since negatively charged electrons repel each other, the electrons move away from each other to form a set of closely grouped pathways called subshells. Larger shells have more subshells since larger shells have more electrons. Scientists represent the different subshells with letters.

The first shell is the smallest and has only one subshell denoted by the letter s. The second shell has two subshells, s and p. The third shell has s, p, and d subshells, while the fourth shell has s, p, d, and f subshells. Each type of subshell has a maximum electron capacity. An s subshell has a maximum electron capacity of 2 electrons, a p subshell 6 electrons, a d subshell 10 electrons, and an f subshell 14 electrons.

To note the shell and subshell of any electron in an atom, you write the shell number followed by the subshell letter. For instance, 2p means the second shell, the p subshell. 4s means the fourth shell, the s subshell.

Electron Configuration

To describe all the electrons in an atom, you write the element's electron configuration. The electron configuration

is a list of the subshells that contain electrons. You write a superscript with each subshell to indicate the number of electrons in that subshell. The order which electrons enter subshells is 1s, 2s, 2p, 3s, 3p, 4s, 3d, 4p, 5s, 4d, 5p, 6s, 4f, 5d, 6p, 7s, 5f, and 6d.

As an example helium, He, has an atomic number of 2 and therefore has 2 electrons. The electron configuration for He is $1s^2$. The 1 indicates the first shell, the s the subshell. The superscript 2 indicates the number of electrons in that subshell. Oxygen, O, has 8 electrons. The electron configuration is $1s^2\ 2s^2\ 2p^4$. Notice that electrons fill the 1s subshell first, followed by the 2s and then the 2p. Recall that an s subshell has a maximum electron capacity of 2 electrons, a p subshell 6 electrons, a d subshell 10 electrons, and an f subshell 14 electrons. Note also for oxygen, if you add the superscripts 2, 2, and 4 you get 8, which is the number of electrons in oxygen. Therefore when writing an electron configuration, you begin placing electrons in the first subshell, 1s, then the next subshell, 2s, and so forth until you account for all the electrons in the atom.

Follow along on the periodic table to see how to use the table to determine electron configurations. The first row at the top of the table has only two elements corresponding to the filling of the 1s subshell. The second row contains elements placing their outer electron in a 2s (elements to the right of the row). Elements in the third row fill their

3s or 3p subshells, while in the fourth row elements place their last electron in a 4s, 3d, or 4p subshell. In the fifth row electrons enter the 5s, 4d, or 5p subshells. Elements fill their 6s, 5d, or 6p subshells in the sixth row, while in the seventh row electrons fill the 7s and begin filling the 6d subshell. Note that the two rows at the bottom of the table contain elements which place their last electrons in the 4f and 5f subshells. (2. What are the symbols of the elements that fill their 3s or 3p subshells last?)

Just follow the table from left to right by increasing atomic number to determine the electron notation of an element. Consider the element H. Beginning with F, we go across the first row, then the second row, and so forth until we reach F. Elements in the first row place their electrons in the 1s subshell. The first two elements in the second row place their outer electrons in the 2s subshell. Continuing across the second row, we encounter F as the fifth element on the right side of the table. Hence the configuration for F is $1s^2\ 2s^2\ 2p^5$. For the element gold, Au, which has 79 electrons, the configuration is $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6\ 5s^2\ 4d^{10}\ 5p^6\ 6s^2\ 4f^{14}\ 5d^9$. (3. What is the electron configuration for Mg?)

Forming Compounds

Atoms of elements are not always satisfied with the number of electrons they have on their outer shell. To

change this situation, atoms combine with other atoms by gaining or losing electrons. A compound forms when two or more different kinds of atoms combine. You write the formula of a compound by using the symbols of the elements in the compound. For instance, sodium chloride is $NaCl$.

You use the number of outer shell electrons to determine how many electrons an atom gains or loses when forming a compound. Many compounds have a metal atom combined to a nonmetal. Metals generally have 1, 2, or 3 outer shell electrons while nonmetals have 5, 6, or 7 electrons on the outer shell. Atoms of metals lose all of their outer shell electrons when metals form compounds. Nonmetals gain electrons until 8 electrons are on the outer shell of the atoms, since 8 electrons is a very stable arrangement.

Therefore a metal atom like sodium with 1 outer shell electron gives that electron to a chlorine atom which has 7 electrons to give it 8 electrons. Since Na and Cl react in a one to one ratio, the formula of the compound is $NaCl$.

Consider magnesium, Mg, and chlorine. Magnesium has 2 outer shell electrons to give to chlorine. However, chlorine has 7 electrons and will gain only one more. Therefore, a second atom of chlorine gains the second electron that magnesium loses. The formula of the compound is $MgCl_2$. Notice the subscript 2 indicates that two chlorine atoms react with every 1 Mg atom.

Until now you used the electron configuration to determine the number of outer shell electrons for an atom. An alternative way to determine the number of outer shell electrons is to use the numbers above the A columns on the periodic table. All elements in a specific A column have the same number of outer shell electrons. The number of outer shell electrons is equal to the number appearing with the A. Atoms of all other elements generally have 2 electrons on their outermost shell. Now consider magnesium and oxygen. Mg is in group IIA while O is in group VIA. Magnesium has 2 outer shell electrons and oxygen has 6 outer shell electrons. Mg loses 2 electrons and O gains 2 electrons to become stable. Therefore, the formula of the compound is MgO, since the atoms react in a 1 to 1 ratio. (4. How many outer shell electrons does an atom of F have?) (5. What is the formula of the compound containing Zn and Cl?)

Periodic Table

You will now learn information about groups of elements by looking at the periodic table as a whole. Beginning with H in the upper left-hand corner, scientists arranged the elements from left to right by increasing atomic number. In addition, elements having similar chemical properties appear above and below each other. Elements above and below each other are a family of elements. Thus, the vertical column of He, Ne, Ar, Kr, Xe, and Rn forms a chemical family. Elements to the left and right of each other form a period. The

horizontal row of elements Li, Be, B, C, N, O, F, and Ne is a period of elements. (6. What are the symbols of the elements in the family with Na?)

Recall that elements in a family have similar chemical properties. If you know some properties about Be, then you will expect similar properties to occur for the other elements in that family. These similar properties result from elements within a family having the same type and number of outer shell electrons. For example, the two families on the far left of the table contain elements that place their last electron in an s subshell. If the outermost electron enters a p subshell, the element is in one of the six families to the far right of the table. If the last electron is a d electron, the element is in one of the three long rows in the center of the table. Finally, the elements at the bottom of the table place their last electron in an f subshell.

Metals and Nonmetals

Another useful piece of information about an element is whether the element is a metal or nonmetal. Notice on the table the dark black zig-zag line beginning between B and Al and continuing downward and to the right. The zig-zag line roughly groups elements into metals and nonmetals. Elements to the left of the line are metals, while elements to the right of the line are nonmetals. Elements along the line sometimes have properties of both metals and nonmetals.

Metals are to the left of the zig-zag line. Metals have many physical properties common with other metals. Copper, Cu, for example has a shiny luster and is a good conductor of electricity and heat. Since copper is a metal, copper loses its outer shell electrons during many chemical reactions.

Elements to the right of the zig-zag line are nonmetals. A common nonmetal is sulfur, S. Nonmetals like sulfur have properties opposite the properties of metals. Sulfur has a dull yellow color and is a poor conductor of electricity and heat. During many chemical reactions sulfur gains electrons from metals, since sulfur has 6 outer shell electrons. (7. What is the symbol of an element that is a good conductor of electricity?)

Trends in the Properties of Elements

Recall that elements within a family have similar chemical properties. The properties are similar because these elements all have the same number and type of outer shell electrons. Yet within a family there are some important trends of interest. First look at the family of metals beginning with Be. All of the metals in this family have an outermost configuration of s^2. Furthermore, going down the family each element has a new shell since additional electrons are in the atom. With the addition of each shell the size of the atom increases. Since metals only have a few electrons on their outermost shell, metals lose these

electrons during chemical reaction. Thus metals at the bottom of a family lose electrons easier and faster, since the electrons are farther from the pull of the nucleus. The rate of reactivity for the metals Be, Mg, Ca, Sr, Ba, and Ra is Ra reacts faster than Ba, Ba reacts faster than Sr, and so forth. Be is the least reactive metal in this family. (8. In the family containing K, how many atoms are larger in size than K?)

Trends are also important in nonmetallic families. A unique family of nonmetals is the noble gases, the family to the far right of the table. These gases are unlike the other elements, since these gases are very stable and very seldom react chemically. These stable gases have 8 electrons on their outermost shell (except He). Eight outer shell electrons produce a stable arrangement, and the other elements try to acquire 8 electrons when the elements form compounds.

Other nonmetals are more reactive. Within the family of nonmetals beginning with oxygen, O, the size of the nonmetal atom increases as you go down the family, since each element adds a new shell. Nonmetals have 5, 6, or 7 electrons on their outermost shell, so these elements gain a few electrons to become stable. Since nonmetals attract electrons, the element within a family where the electrons are closest to the nucleus is the most reactive member of that family. In the family beginning with O, O is the most reactive nonmetal and Po is the least reactive member of that family. (10. What is the symbol of a nonmetal that is more reactive than Cl?)

Going across a period the elements change from metals to nonmetals, since the number of outermost electrons changes from 1 to 8. Period 4, K to Kr, contains elements that have electrons in their first four shells. Since each element differs from the element before it by one proton, the added proton pulls the electrons closer to the nucleus, so the size of the atoms decreases slightly. The slight decrease in size in going from K to Ca makes it slightly harder for Ca to lose an electron. In addition, it is more difficult for atoms to lose 2 electrons than just 1. Therefore K is more reactive than Ca. Generally the most reactive metal is farthest to the left and to the bottom of the table.

Nonmetals, on the other hand, gain electrons. It is easier for atoms to gain 1 electron than to gain more than 1. Thus the most reactive nonmetal is farthest to the right and to the top of the table.

Table with Added Numerical Information (N)

Please read the following instructions VERY CAREFULLY.

In this packet you have three types of chemistry materials. First you have 7-8 pages of written material describing topics you learn about in chemistry.

Second, you have two 1-page diagrams. The diagrams show how the topics you read relate to each other.

Finally, you have a copy of the periodic table. Since you will read material that refers to the periodic table, BE SURE TO LOOK AT THE PERIODIC TABLE AS YOU READ.

Your job is to read the written material carefully. In addition, study carefully the diagrams. Refer to the periodic table as you read the material and study the diagram. In addition, there are questions in the written materials and after the diagrams. Answer all the questions on the answer sheet provided.

Take as much time as you need on each page, but once you complete a page, turn it over and do not go back to that page. Learn as much as possible. Later you will take a test covering the material.

Chemistry and the Atom

Atoms are the building blocks of all chemical substances. Atoms consist of two main regions: the center and the space around the center. The nucleus is the name for the dense, center portion of the atom. Two particles, protons and neutrons, make up the nucleus. Protons are particles with a positive charge while neutrons have no charge.

The space around the nucleus is the second region of an atom. Negatively charged particles called electrons spin around the nucleus. The positively charged protons in the nucleus pull the negatively charged electrons towards the nucleus, since oppositely charged particles attract.

An element is a substance consisting of atoms that are alike. Atoms are alike if they all have the same number of protons in the nucleus. Scientists have discovered 103 different chemical elements. Scientists grouped these elements according to their properties and displayed them on charts called periodic charts or periodic tables. You will discover why scientists used the term periodic.

Information About Each Element

Each block on the chart stores information about one element. Within each block you will find 6 pieces of information. You will learn about 3 of these pieces of information later. The other three pieces of information are the element's chemical symbol, its atomic mass, and its atomic number. The chemical symbol is a shorthand notation

representing the name of the element. The atomic mass is the average mass of the atoms of an element. Generally you find the atomic mass located below the symbol of the element.

The atomic number indicates the number of positively charged protons in the nucleus. The atomic number is always a whole number since there are no fractions of protons. Typically you find the atomic number located above the symbol of the element.

Usually there are as many electrons spinning around the nucleus as there are protons in the nucleus. So if you know the atomic number, you know both the number of protons in the nucleus and the number of electrons spinning outside the nucleus.

For the element beryllium, Be, the atomic number is 4. Every atom of beryllium has 4 protons in the nucleus and 4 electrons spinning around the nucleus. (1. What is the atomic number for Na and how many electrons does an atom of Na have?)

The element cesium, Cs, has 55 protons in the nucleus and 55 electrons around the nucleus. Fifty-five electrons is a lot. Since all the electrons are negatively charged, they repel each other and spread apart. As the electrons spread apart they move to separate pathways. These pathways are called shells. You indicate shells by giving each shell a number. The first shell is the one closest to the

nucleus. The next shell away from the nucleus is the second shell, then the third shell and so on. Shells farther from the nucleus have larger paths around the nucleus. Furthermore, shells with larger paths have a larger electron capacity of 2 electrons. The second shell has a capacity of 8 electrons, the third shell 18, and the fourth shell 32. Eight, 18, and 32 electrons is still a lot. Since negatively charged electrons repel each other, the electrons move away from each other to form a set of closely grouped pathways called subshells. Larger shells have more subshells since larger shells have more electrons. Scientists represent the different subshells with letters.

The first shell is the smallest and has only one subshell denoted by the letter s. The second shell has two subshells, s and p. The third shell has s, p, and d subshells, while the fourth shell has s, p, d, and f subshells. Each type of subshell has a maximum electron capacity. An s subshell has a maximum electron capacity of 2 electrons, a p subshell 6 electrons, a d subshell 10 electrons, and an f subshell 14 electrons.

To note the shell and subshell of any electron in an atom, you write the shell number followed by the subshell letter. For instance, 2p means the second shell, the p subshell. 4s means the fourth shell, the s subshell.

Electron Configuration

To describe all the electrons in an atom, you write the element's electron configuration. The electron

configuration is a list of the subshells that contain electrons. You write a superscript with each subshell to indicate the number of electrons in that subshell. The order which electrons enter subshells is 1s, 2s, 2p, 3s, 3p, 4s, 3d, 4p, 5s, 4d, 5p, 6s, 4f, 5d, 6p, 7s, 5f, and 6d.

As an example, helium, He, has an atomic number of 2 and therefore has 2 electrons. The electron configuration for He is $1s^2$. The 1 indicates the first shell, the s the subshell. The superscript 2 indicates the number of electrons in that subshell. Oxygen, O, has 8 electrons. The electron configuration is $1s^2\ 2s^2\ 2p^4$. Notice that electrons fill the 1s subshell first, followed by the 2s and then the 2p. Recall that an s subshell has a maximum electron capacity of 2 electrons, a p subshell 6 electrons, a d subshell 10 electrons and an f subshell 14 electrons. Note also for oxygen, if you add the superscripts 2, 2, and 4, you get 8, which is the number of electrons in oxygen. Therefore when writing an electron configuration, you begin placing electrons in the first subshell, 1s, then the next subshell, 2s, and so forth until you account for all the electrons in an atom.

Follow along on the periodic table to see how to use the table to determine electron configurations. (Note the subshell notation of the last electron is in the upper left-hand corner of each block. Find the notation for H.) The first row at the top of the table has only two elements corresponding to the filling of the 1s subshell. The second

row contains elements placing their outer electron in a 2s (elements to the left of the row) or a 2p subshell (elements to the right of the row). Elements in the third row fill their 3s or 3p subshells, while in the fourth row elements place their last electron in a 4s, 3d, or 4p subshell. In the fifth row electrons enter the 5s, 4d, or 5p subshells. Elements fill their 6s, 5d, or 6p subshells in the sixth row, while in the seventh row, electrons fill the 7s and begin filling the 6d subshell. Note that the two rows at the bottom of the table contain elements which place their last electrons in the 4f and 5f subshells. (2. What are the symbols of the elements that fill their 3s or 3p subshells last?)

Just follow the table from left to right by increasing atomic number to determine the electron notation of an element. Consider the element F. Beginning with H, we go across the first row, then the second row, and so forth until we reach F. Elements in the first row place their electrons in the 1s subshell. The first two elements in the second row place their outer electrons in the 2s subshell. Continuing across the second row, we encounter F as the fifth element on the right side of the table. Hence the configuration is $1s^2\ 2s^2\ 2p^5$. For the element gold, Au, which has 79 electrons, the configuration is $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6\ 5s^2\ 4d^{10}\ 5p^6\ 6s^2\ 4f^{14}\ 5d^9$. (3. What is the electron configuration for Mg?)

Forming Compounds

Atoms of elements are not always satisfied with the number of electrons they have on their outer shell. To change this situation, atoms combine with other atoms by gaining or losing electrons. A compound forms when two or more different kinds of atoms combine. You write the formula of a compound by using the symbols of the elements in the compound. For instance, sodium chloride is NaCl.

You use the number of outer shell electrons to determine how many electrons an atom loses or gains when forming a compound. Many compounds have a metal atom combined to a nonmetal. Metals generally have 1, 2, or 3 outer shell electrons while nonmetals have 5, 6, or 7 electrons on the outer shell. Atoms of metals lose all of their outer shell electrons when metals form compounds. Nonmetals gain electrons until 8 electrons are on the shell of the atom, since 8 electrons is a very stable arrangement.

Therefore, a metal atom like sodium with 1 outer shell electron gives that electron to a chlorine atom which has 7 to give it 8 electrons. Since Na and Cl react in a one to one ratio, the formula of the compound is NaCl.

Consider magnesium, Mg, and chlorine. Magnesium has 2 outer shell electrons to give to chlorine. However, chlorine has 7 electrons and gains only one more. Therefore a second atom of chlorine gains the second electron that magnesium loses. The formula of the compound is $MgCl_2$.

Notice the subscript 2 indicates that two chlorine atoms react with every 1 Mg atom.

Until now you used the electron configuration to determine the number of outer shell electrons for an atom. An alternative way to determine the number of outer shell electrons is to use the number in the lower left-hand corner of each block. These numbers represent the number of electrons on the outer shell of the atom. (Locate this number for H.) Now consider magnesium and oxygen. Magnesium has 2 outer shell electrons and oxygen has 6 outer shell electrons. Mg loses 2 electrons and O gains 2 electrons to become stable. Therefore, the formula of the compound is MgO, since the atoms react in a 1 to 1 ratio. (4. How many outer shell electrons does an atom of F have?) (5. What is the formula of the compound containing Zn and Cl?)

Periodic Table

You will now learn information about groups of elements by looking at the periodic table as a whole. Beginning with H in the upper left-hand corner, scientists arranged the elements from left to right by increasing atomic number. In addition, elements having similar chemical properties appear above and below each other. Elements above and below each other are a family of elements. Thus, the vertical column of He, Ne, Ar, Kr, Xe, and Rn forms a chemical family. Elements to the left and right of each other form a period. The horizontal row of elements Li, Be, B, C, N, O, F, and Ne

is a period of elements. (6. What are the symbols of the elements in the family with Na?)

Recall that elements in a family have similar chemical properties. If you know some properties about Be, then you expect similar properties to occur for the other elements in that family. These similar properties result from elements within a family having the same type and number of outer shell electrons. For example, the two families on the far left of the table contain elements that place their last electron in an s subshell. If the outermost electron enters a p subshell, the element is in one of the six families to the far right of the table. If the last electron is a d electron, the element is in one of the three long rows in the center of the table. Finally, the elements at the bottom of the table place their last electron in an f subshell.

Metals and Nonmetals

Another useful piece of information about an element is whether the element is a metal or nonmetal. Notice on the table the dark black zig-zag line beginning between B and Al and continuing downward and to the right. The zig-zag line roughly groups elements into metals and nonmetals. Elements to the left of the line are metals, while elements to the right of the line are nonmetals. Elements along the line sometimes have properties of both metals and nonmetals.

Metals are to the left of the zig-zag line. Metals have many physical properties common with other metals.

Copper, Cu, for example, has a shiny luster and is a good conductor of electricity and heat. Since copper is a metal, copper loses its outer shell electrons during many chemical reactions.

Elements to the right of the zig-zag line are nonmetals. A common nonmetal is sulfur, S. Nonmetals like sulfur have properties opposite the properties of metals. Sulfur has a dull yellow color and is a poor conductor of electricity and heat. During many chemical reactions sulfur gains electrons from metals, since sulfur has 6 outer shell electrons.
(7. What is the symbol of an element that is a good conductor of electricity?)

Trends in the Properties of Elements

Recall that elements within a family have similar chemical properties. The properties are similar because these elements all have the same number and type of outer shell electrons. Yet within a family there are some important trends of interest. First look at the family of metals beginning with Be. All of the metals in this family have an outermost configuration of s^2. Furthermore, going down the family each element has a new shell since additional electrons are in the atom. With the addition of each shell the size of the atom increases. (Note the number to the left of the symbol in each block represents the relative size of the atom.) Locate the size for H. Since metals only have a few electrons on their outermost shell, metals lose these

electrons during chemical reactions. Thus metals at the bottom of a family lose electrons easier and faster, since the electrons are farther from the pull of the nucleus. The rate of reactivity for the metals Be, Mg, Ca, Sr, Ba, and Ra is Ra reacts faster than Ba, Ba reacts faster than Sr, and so forth. Be is the least reactive metal in this family. (8. In the family containing K, how many atoms are larger in size than K?) (9. What is the symbol of a metal that is more reactive than K?)

Trends are also important in nonmetallic families. A unique family of nonmetals is the noble gases, the family to the far right of the table. These gases are unlike the other elements, since these gases are very stable and seldom react chemically. These stable gases have 8 electrons on their outermost shell (except He). Eight outer shell electrons produce a stable arrangement, and the other elements try to acquire 8 electrons when the elements form compounds.

Other nonmetals are more reactive. Within the family of nonmetals beginning with oxygen, O, the size of the nonmetal atom increases as you go down the family, since each element adds a new shell. Nonmetals have 5, 6, or 7 electrons on their outermost shell, so these elements gain a few electrons to become stable. Since nonmetals attract electrons, the element within a family where the electrons are closest to the nucleus is the most reactive member of that family. In the family beginning with O, O is the most

reactive nonmetal, and Po is the least reactive member of the family. (10. What is the symbol of a nonmetal that is more reactive than Cl?)

Going across a period the elements change from metals to nonmetals since the number of outermost electrons changes from 1 to 8. Period 4, K to Kr, contains elements that have electrons in their first four shells. Since each element differs from the element before it by one proton, the added proton pulls the electrons closer to the nucleus, so the size of the atoms decreases slightly. The slight decrease in size in going from K to Ca makes it slightly harder for Ca to lose an electron. In addition, it is more difficult for atoms to lose 2 electrons than just 1. Therefore, K is more reactive than Ca. Generally the most reactive metal is farthest to the left and the bottom of the table.

Nonmetals, on the other hand, gain electrons. It is easier for atoms to gain 1 electron than to gain more than 1 electron. Thus, the most reactive nonmetal is farthest to the right and to the top of the table.

Table with Added Visual Information (V)

Please read the following instructions very carefully.

In this packet you have two types of chemistry materials. First you have 7-8 pages of written material describing topics you learn about in chemistry.

Second you have a copy of a periodic table. Since you will read material that refers to the periodic table, BE SURE TO LOOK AT THE PERIODIC TABLE AS YOU READ.

Your job is to read the written material carefully. Refer to the periodic table as you read the material. In addition, there are questions in the written materials. Answer all the questions on the answer sheet provided.

Take as much time as you need on each page, but once you complete a page, turn it over and do not go back to that page. Learn as much as possible. Later you will take a test covering the material.

Chemistry and the Atom

Atoms are the building blocks of all chemical substances. Atoms consist of two main regions: the center and the space around the center. The nucleus is the name for the dense, center portion of the atom. Two particles, protons and neutrons, make up the nucleus. Protons are particles with a positive charge while neutrons have no charge.

The space around the nucleus is the second region of an atom. Negatively charged particles called electrons spin around the nucleus. The positively charged protons in the nucleus pull the negatively charged electrons towards the nucleus, since oppositely charged particles attract.

An element is a substance consisting of atoms that are alike. Atoms are alike if they all have the same number of protons in the nucleus. Scientists have discovered 103 different chemical elements. Scientists grouped these elements according to their properties and displayed them on charts called periodic charts or periodic tables. You will discover why scientists used the term periodic.

Information About Each Element

Each block on the chart stores information about one element. Within each block you will find six pieces of information. You will learn about three of these pieces of information later. The other three pieces of information are the element's chemical symbol, its atomic mass, and its atomic number. The chemical symbol is a shorthand notation

representing the name of the element. The atomic mass is the average mass of the atoms of an element. Generally, you find the atomic mass located below the symbol of an element.

The atomic number indicates the number of positively charged protons in the nucleus. The atomic number is always a whole number since there are no fractions of protons. Typically you find the atomic number located above the symbol of the element.

Usually there are as many electrons spinning around the nucleus as there are protons in the nucleus. So if you know the atomic number, you know both the number of protons in the nucleus and the number of electrons spinning outside the nucleus.

For the element beryllium, Be, the atomic number is 4. Every atom of beryllium has 4 protons in the nucleus and 4 electrons spinning around the nucleus. (1. What is the atomic number for Na and how many electrons does an atom of Na have?)

The element cesium, Cs, has 55 protons in the nucleus and 55 electrons around the nucleus. Fifty-five is a lot. Since all the electrons are negatively charged, they repel each other and spread apart. As the electrons spread apart they move to separate pathways. These pathways are called shells. You indicate shells by giving each shell a number. The first shell is the one closest to the nucleus. The next

shell away from the nucleus is the second shell, then the third shell and so on. Shells farther from the nucleus have larger paths around the nucleus. Furthermore shells with larger paths have a larger electron capacity than shells closer to the nucleus. The first shell has an electron capacity of 2 electrons. The second shell has a capacity of 8 electrons, the third shell 18 electrons, and the fourth shell 32 electrons. Eight, 18, and 32 electrons is still a lot. Since negatively charged electrons repel each other, the electrons move away from each other to form a set of closely grouped pathways called subshells. Larger shells have more subshells since larger shells have more electrons. Scientists represent the different subshells with letters.

The first shell is the smallest and has only one subshell denoted by the letter s. The second shell has two subshells, s and p. The third shell has s, p, and d subshells, while the fourth shell has s, p, d, and f subshells. Each type of subshell has a maximum electron capacity. An s subshell has a maximum electron capacity of 2 electrons, a p subshell 6 electrons, a d subshell 10 electrons, and an f subshell 14 electrons.

To note the shell and subshell of any electron in an atom, you write the shell number followed by the subshell letter. For instance 2p means the second shell, the p subshell. 4s means the fourth shell, the s subshell.

Electron Configuration

To describe all the electrons in an atom, you write the element's electron configuration. The electron configuration is a list of the subshells that contain electrons. You write a superscript with each subshell to indicate the number of electrons in that subshell. The order which electrons enter subshells is 1s, 2s, 2p, 3s, 3p, 4s, 3d, 4p, 5s, 4d, 5p, 6s, 4f, 5d, 6p, 7s, 5f, and 6d.

As an example helium, He, has an atomic number of 2 and therefore has 2 electrons. The electron configuration for He is $1s^2$. The 1 indicates the first shell, the s the subshell. The superscript 2 indicates the number of electrons in that subshell. Oxygen, O, has 8 electrons. The electron configuration for O is $1s^2\ 2s^2\ 2p^4$. Notice that electrons fill the 1s subshell first, followed by the 2s and then the 2p. Recall that an s subshell has a maximum electron capacity of 2 electrons, a p subshell 6 electrons, a d subshell 10 electrons, and an f subshell 14 electrons. Note also for oxygen, if you add the superscripts 2, 2, and 4, you get 8, which is the number of electrons in oxygen. Therefore when writing an electron configuration, you begin placing electrons in the first subshell, 1s, then the next subshell, 2s, and so forth until you account for all the electrons in the atom.

Follow along on the periodic table to see how to use the table to determine electron configuration. (Note that the

subshell notation for the last electron is in the upper left-hand corner of each block. Find the notation for H. Note also that shading to the left of a symbol represents a filled subshell, Be.) The first row at the top of the table has only two elements corresponding to the filling of the 1s subshell. The second row contains elements placing their outer electron in a 2s (elements at the left of the row) or a 2p subshell (elements at the right of the row). Elements in the third row fill their 3s or 3p subshells, while in the fourth row elements place their last electrons in a 4s, 3d, or 4p subshell. In the fifth row electrons enter the 5s, 4d, or 5p subshells. Elements fill their 6s, 5d, or 6p subshells in the sixth row, while in the seventh row electrons fill the 7s and begin filling the 6d subshell. Note that the two rows at the bottom of the table contain elements which place their last electrons in the 4f and 5f subshells. (2. What are the symbols of the elements that fill their 3s or 3p subshells last?)

Just follow the table from left to right by increasing atomic number to determine the electron notation of an element. Consider the element F. Beginning with H, we go across the first row, then the second row, and so forth until we reach F. Elements in the first row place their electrons in the 1s subshell. The first two elements in the second row place their outer electrons in the 2s subshell. Continuing across the second row, we encounter F as the

fifth element on the right side of the table. Hence, the configuration for F is $1s^2\ 2s^2\ 2p^5$. For the element gold, Au, which has 79 electrons, the configuration is $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6\ 5s^2\ 4d^{10}\ 5p^6\ 6s^2\ 4f^{14}\ 5d^9$. (3. What is the electron configuration for Mg?)

Forming Compounds

Atoms of elements are not always satisfied with the number of electrons they have on their outer shell. To change this situation, atoms combine with other atoms by gaining or losing electrons. A compound forms when two or more different kinds of atoms combine. You write the formula of a compound by using the symbols of the elements in the compound. For instance, sodium chloride is NaCl.

You use the number of outer shell electrons to determine how many electrons an atom loses or gains when forming a compound. Many compounds have a metal atom combined with a nonmetal atom. Metals generally have 1, 2, or 3 outer shell electrons while nonmetals have 5, 6, or 7 electrons on the outer shell. Atoms of metals lose all of their outer shell electrons when metals form compounds. Nonmetals gain electrons until 8 electrons are on the outer shell of the atoms, since 8 electrons is a very stable arrangement.

Therefore, a metal atom like sodium with 1 outer shell electron gives that electron to a chlorine atom which has 7 electrons to give it 8 electrons. Since Na and Cl react in a 1 to 1 ratio, the formula of the compound is NaCl.

Consider magnesium and chlorine. Magnesium has 2 outer shell electrons to give to chlorine. However, chlorine has 7 electrons and will gain only 1 more. Therefore a second atom of chlorine gains the second electron that magnesium loses. The formula of the compound is $MgCl_2$. Notice that the subscript 2 indicates that two chlorine atoms react with every 1 Mg atom.

Until now you used the electron configuration to determine the number of outer shell electrons for an atom. An alternative way to determine the number of outer shell electrons is to use the numbers with the letter e in the lower left-hand corner of each block. The number and the letter e are next to the semi-circle. These numbers represent the number of electrons on the outer shell of the atom. The letter e represents electrons. (Locate this number for H.) Now consider magnesium and oxygen. Magnesium has 2 outer shell electrons and oxygen has 6 outer shell electrons. Mg loses 2 electrons and O gains 2 electrons to become stable. Therefore the formula of the compound is MgO, since the atoms react in a one to one ratio. (4. How many outer shell electrons does an atom of F have?) (5. What is the formula of the compound containing Zn and Cl?)

Periodic Table

You will now learn information about groups of elements by looking at the periodic table as a whole. Beginning with H in the upper left-hand corner, scientists arranged the

elements from left to right by increasing atomic number. In addition, elements having similar chemical properties appear above and below each other. Elements above and below each other are a family of elements. Thus, the vertical column of He, Ne, Ar, Kr, Xe, and Rn forms a chemical family. Elements to the left and right of each other form a period. The horizontal row of elements Li, Be, B, C, N, O, F, and Ne is a period of elements. (6. What are the symbols of the elements in the family with Na?)

Recall that elements in a family have similar chemical properties. If you know some properties about Be, then you expect similar properties to occur for the other elements in that family. These similar properties result from elements within a family having the same type and number of outer shell electrons. For example, the two families on the far left of the table (outlined in red) contain elements that place their last electron in an s subshell. If the outermost electron enters a p subshell, the element is in one of the six families to the far right of the table (outlined in blue). If the last electron is a d electron, the element is in one of the three long rows in the center of the table (outlined in black). Finally, the elements at the bottom of the table (outlined in green) place their last electron in an f subshell.

Metals and Monmetals

Another useful piece of information about an element is whether the element is a metal or nonmetal. Notice on the

table the dark black zig-zag line beginning between B and Al and continuing downward and to the right. The zig-zag line roughly groups elements into metals and nonmetals. Elements to the left of the line are metals, while elements to the right of the line are nonmetals. Elements along the line sometimes have properties of both metals and nonmetals.

Metals are to the left of the zig-zag line. Metals have many physical properties common with other metals. Copper, Cu, for example has a shiny luster and is a good conductor of electricity and heat. Since copper is a metal, copper loses its outer shell electrons during many chemical reactions.

Elements to the right of the zig-zag line are nonmetals. A common nonmetal is sulfur, S. Nonmetals like sulfur have properties opposite the properties of metals. Sulfur has a dull yellow color and is a poor conductor of electricity and heat. During many chemical reactions sulfur gains electrons from metals, since sulfur has 6 outer shell electrons.
(7. What is the symbol of an element that is a good conductor of electricity?)

Trends in the Properties of Elements

Recall that elements within a family have similar chemical properties. The properties are similar because these elements all have the same number and type of outer shell electrons. Yet within a family there are some important trends of interest. First look at the family of metals

beginning with Be. All of the metals in this family have an outermost configuration of s^2. Furthermore, going down the family each element has a new shell since additional electrons are in the atom. With the addition of each shell the size of the atom increases. The semi-circle, (Mg, next to the symbol of each element represents the relative size of the atom. The larger semi-circles represent the larger atoms. (Locate the semi-circle for H.) Since metals only have a few electrons on their outermost shell, metals lose these electrons during chemical reactions. Thus metals at the bottom of a family lose electrons easier and faster, since the electrons are farther from the pull of the nucleus. The rate of reactivity for the metals Be, Mg, Ca, Sr, Ba, and Ra, is Ra reacts faster than Ba, Ba reacts faster than Sr, and so forth. Be is the least reactive metal in this family. (8. In the family containing K, how many atoms are larger in size than K?) (9. What is the symbol of a metal that is more reactive than K?)

Trends are also important in nonmetallic families. A unique family of nonmetals is the noble gases, the family to the far right of the table. These gases are unlike the other elements, since these gases are very stable and very seldom react chemically. These stable gases have 8 electrons on their outermost shell (except He). Eight outer shell electrons produce a stable arrangement, and other elements try to acquire 8 electrons when the elements form compounds.

Other nonmetals are more reactive. Within the family of nonmetals beginning with oxygen, O, the size of the nonmetal atom increases as you go down the family, since each element adds a new shell. Nonmetals have 5, 6, or 7 electrons on their outermost shell, so these elements gain a few electrons to become stable. Since nonmetals attract electrons, the element within a family where the electrons are closest to the nucleus is the most reactive member of that family. In the family beginning with O, O is the most reactive nonmetal and Po is the least reactive member of the family. (10. What is the symbol of a nonmetal that is more reactive than Cl?)

Going across a period the elements change from metals to nonmetals, since the number of outermost electrons changes from 1 to 8. Period 4, K to Kr, contains elements that have electrons in their first four shells. Since each element differs from the element before it by one proton, the added proton pulls the electrons closer to the nucleus, so the size of the atoms decreases slightly. The slight decrease in size in going from K to Ca makes it slightly harder for Ca to lose an electron. In addition, it is more difficult for atoms to lose 2 electrons than just 1. Therefore K is more reactive than Ca. Generally, the most reactive metal is farthest to the left and to the bottom of the table.

Nonmetals, on the other hand, gain electrons. It is easier for atoms to gain 1 electron than to gain more than 1. Thus, the most reactive nonmetal is farthest to the right and to the top of the table.

APPENDIX B
TRADITIONAL AND MODIFIED PERIODIC TABLES
(Reduced for Presentation Here)

PERIODIC TABLE

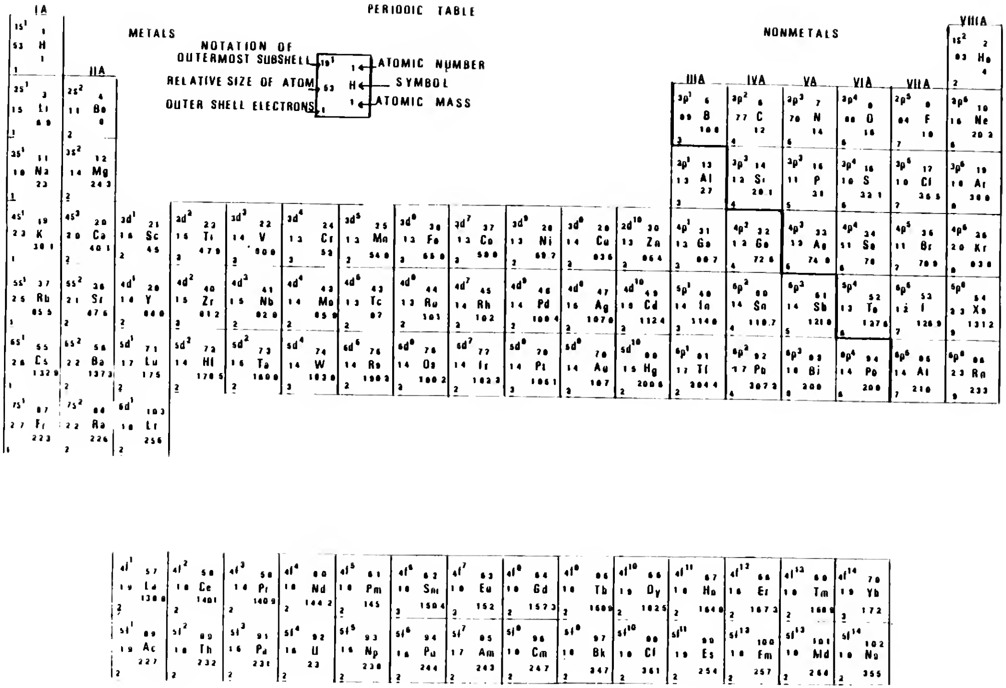
METALS | NONMETALS

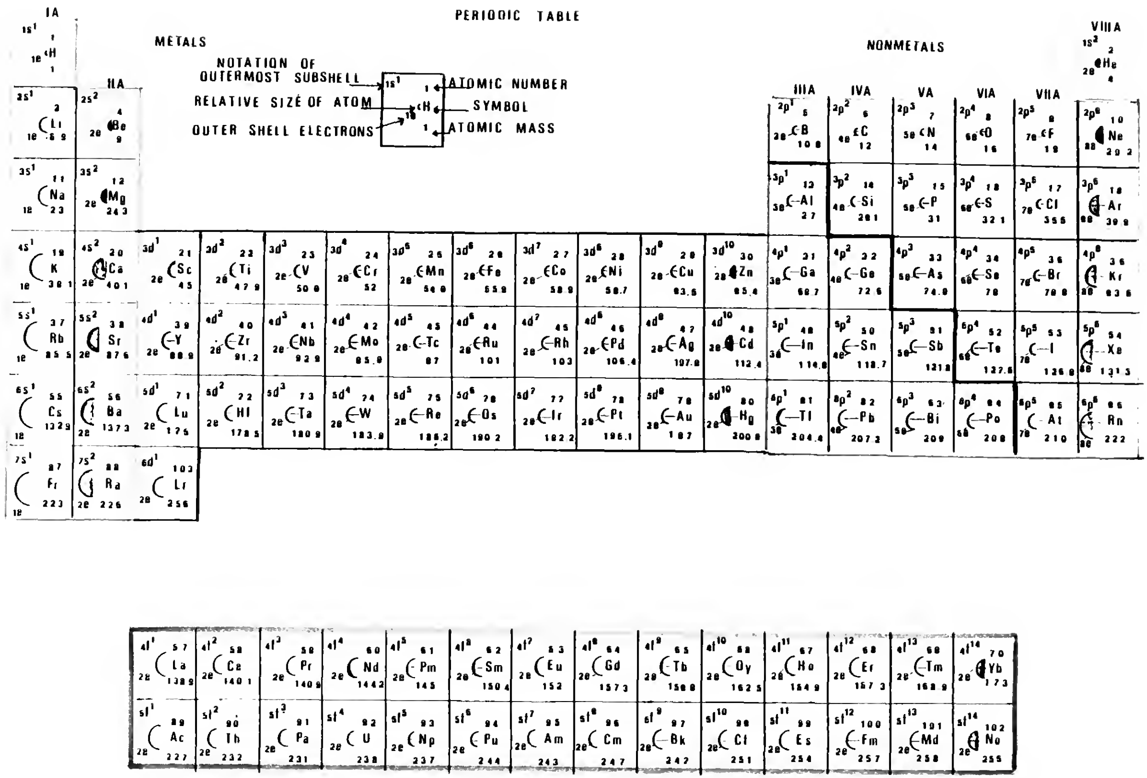
1 H 1

ATOMIC NUMBER / SYMBOL / ATOMIC MASS

IA	IIA											IIIA	IVA	VA	VIA	VIIA	VIIIA
1 H 1																	2 He 4
3 Li 6.9	4 Be 9											5 B 10.8	6 C 12	7 N 14	8 O 16	9 F 19	10 Ne 20.2
11 Na 23	12 Mg 24.3											13 Al 27	14 Si 28.1	15 P 31	16 S 32.1	17 Cl 35.5	18 Ar 39.9
19 K 39.1	20 Ca 40.1	21 Sc 45	22 Ti 47.9	23 V 50.9	24 Cr 52	25 Mn 54.9	26 Fe 55.9	27 Co 58.9	28 Ni 58.7	29 Cu 63.5	30 Zn 65.4	31 Ga 69.7	32 Ge 72.6	33 As 74.9	34 Se 79	35 Br 79.9	36 Kr 83.8
37 Rb 85.5	38 Sr 87.6	39 Y 88.9	40 Zr 91.2	41 Nb 92.9	42 Mo 95.9	43 Tc 97	44 Ru 101	45 Rh 103	46 Pd 106.4	47 Ag 107.9	48 Cd 112.4	49 In 114.8	50 Sn 118.7	51 Sb 121.8	52 Te 127.6	53 I 126.9	54 Xe 131.2
55 Cs 132.9	56 Ba 137.3	71 Lu 175	72 Hf 178.5	73 Ta 180.9	74 W 183.8	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.1	79 Au 197	80 Hg 200.6	81 Tl 204.4	82 Pb 207.2	83 Bi 209	84 Po 209	85 At 210	86 Rn 222
87 Fr 223	88 Ra 226	103 Lr 256															

57 La 138.9	58 Ce 140.1	59 Pr 140.9	60 Nd 144.2	61 Pm 145	62 Sm 150.4	63 Eu 152	64 Gd 157.3	65 Tb 158.9	66 Dy 162.5	67 Ho 164.9	68 Er 167.3	69 Tm 168.9	70 Yb 173
89 Ac 227	90 Th 232	91 Pa 231	92 U 238	93 Np 237	94 Pu 244	95 Am 243	96 Cm 247	97 Bk 247	98 Cf 251	99 Es 254	100 Fm 257	101 Md 258	102 No 256


PERIODIC TABLE
METALS
NONMETALS
NOTATION OF OUTERMOST SUBSHELL
RELATIVE SIZE OF ATOM
OUTER SHELL ELECTRONS
ATOMIC NUMBER
SYMBOL
ATOMIC MASS
IA
IIA
IIIA
IVA
VA
VIA
VIIA
VIIIA
H
He
Li Be B C N O F Ne
Na Mg Al Si P S Cl Ar
K Ca Sc Ti V Cr Mn Fe Co Ni Cu Zn Ga Ge As Se Br Kr
Rb Sr Y Zr Nb Mo Tc Ru Rh Pd Ag Cd In Sn Sb Te I Xe
Cs Ba Lu Hf Ta W Re Os Ir Pt Au Hg Tl Pb Bi Po At Rn
Fr Ra Lr
La Ce Pr Nd Pm Sm Eu Gd Tb Dy Ho Er Tm Yb
Ac Th Pa U Np Pu Am Cm Bk Cf Es Fm Md No


PERIODIC TABLE
METALS
NONMETALS
NOTATION OF OUTERMOST SUBSHELL
RELATIVE SIZE OF ATOM
OUTER SHELL ELECTRONS
ATOMIC NUMBER
SYMBOL
ATOMIC MASS
IA
IIA
IIIA
IVA
VA
VIA
VIIA
VIIIA

APPENDIX C

SCHEMA SHOWING RELATIONSHIPS BETWEEN CHEMISTRY TOPICS

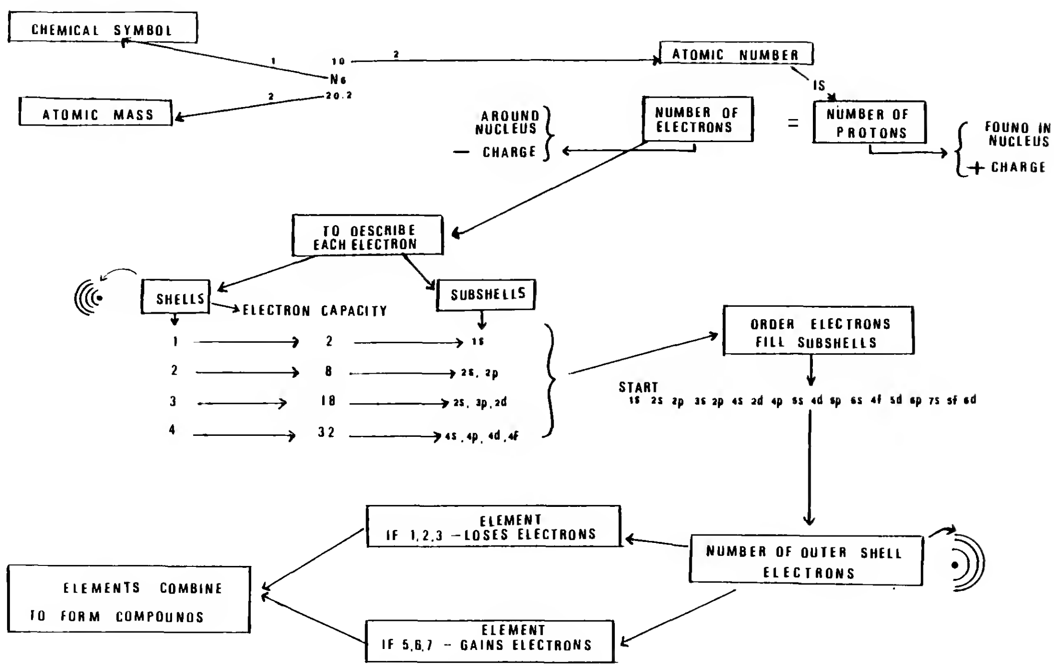
Directions for Diagrams

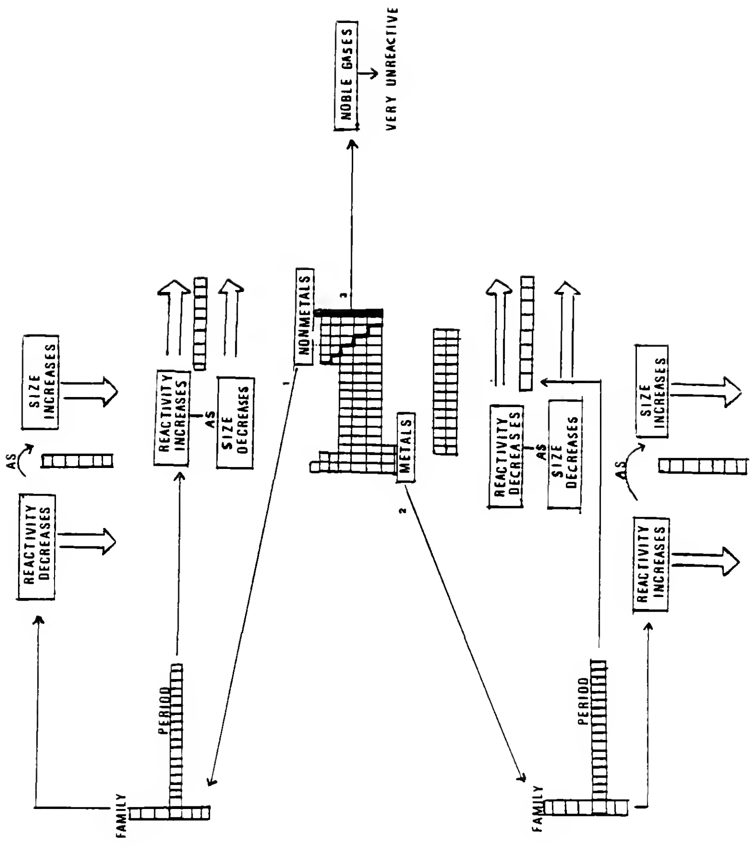
Study the attached diagrams. The first diagram shows the relationships between the different information you obtain from a single block on the periodic table.

The second diagram shows the relationships between groups of elements as you look at the entire periodic table.

Study both the diagrams carefully by following the arrows. Note the relationships between the different pieces of information.

After studying the diagrams, answer the questions following the diagrams on your answer sheet.


CHEMICAL SYMBOL
ATOMIC MASS
1
2
10
Ne
20.2
2
ATOMIC NUMBER
IS
NUMBER OF PROTONS
=
NUMBER OF ELECTRONS
FOUND IN NUCLEUS
+ CHARGE
AROUND NUCLEUS
— CHARGE
TO DESCRIBE EACH ELECTRON
SHELLS
ELECTRON CAPACITY
SUBSHELLS
1
2
3
4
2
8
18
32
1s
2s, 2p
3s, 3p, 3d
4s, 4p, 4d, 4f
ORDER ELECTRONS FILL SUBSHELLS
START
1s 2s 2p 3s 3p 4s 3d 4p 5s 4d 5p 6s 4f 5d 6p 7s 5f 6d
NUMBER OF OUTER SHELL ELECTRONS
ELEMENT
IF 1,2,3 —LOSES ELECTRONS
ELEMENT
IF 5,6,7 – GAINS ELECTRONS
ELEMENTS COMBINE TO FORM COMPOUNDS


NOBLE GASES
VERY UNREACTIVE
NONMETALS
METALS
1
2
3
REACTIVITY DECREASES
AS
SIZE INCREASES
REACTIVITY INCREASES
AS
SIZE DECREASES
FAMILY
PERIOD
REACTIVITY DECREASES
AS
SIZE DECREASES
REACTIVITY INCREASES
AS
SIZE INCREASES
FAMILY
PERIOD

Directions: Answer the following questions. Look at the <u>diagrams</u> to help you answer the questions.

11. What two pieces of information do you use to describe each electron?

12. Which subshell fills after the 3p?

13. Why is it important to know the number of outer shell electrons for an atom?

14. For a family of metals, as the size of the atom increases what happens to the reactivity?

15. Going across any period does the size of the atoms increase or decrease? (from left to right)

16. Is the most reactive nonmetal in a family at the top or bottom of the family?

APPENDIX D

POSTTEST CONTAINING FORCED CHOICE ITEMS AND CONSTRUCTED ANSWER ITEMS

Test Directions

Use the periodic table to help you answer the following questions. Take as much time as you need and place your answers to all the questions on the answer sheet provided. Please do not write on the question sheet.

Directions: For the multiple choice items, place the letter of the correct answer on the answer sheet. For the other items write the answer.

1. Select the symbol of the element that is the best conductor of electricity.

   a. ^{34}Se b. ^{20}Ca c. ^{7}N d. ^{35}Br

2. Which of the following represents a correct chemical formula?

   a. SrBr b. Sr_2Br c. $SrBr_2$ d. Sr_2Br_3

3. Write the symbol of an element that has similar chemical properties as C.

4. Find the symbol of an element that very seldom reacts chemically. Write the symbol.

5. Find a metal in the period containing Mg that reacts faster than Mg. Write the symbol.

6. If Cl gains 1 electron, the electron configuration is:

   a. $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5$

   b. $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^4$

c. $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5\ 4s^1$

d. $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$

7. Find the element that has a total of 6 electrons in its atoms. Write the symbol of the element.

8. Select the element that places its last electron in a d subshell.

   a. ^{12}Mg b. ^{30}Zn c. ^{36}Kr d. ^{92}U

9. Select the most reactive atom.

   a. ^{8}O b. ^{16}S c. ^{34}Se d. ^{52}Te

10. Find and write the symbol of an element that reacts with Ca in a 1 to 1 ratio.

11. Find an element in the family with Br that reacts slower than Br. Write the symbol.

12. Select the atom that most likely gains an additional electron?

   a. ^{3}Li b. ^{9}F c. ^{86}Rn d. ^{87}Fr

13. Find the symbol of an element that reacts with Al. Write the symbol.

14. Write the electron configuration for K.

15. Atoms of the element technetium, Tc, have:

   a. 43 protons, 97 electrons b. 43 protons, 54 electrons c. 43 protons, 43 electrons d. 97 protons, 97 electrons

16. Select the most reactive atom.

   a. ^{3}Li b. ^{11}Na c. ^{19}K d. ^{37}Rb

17. Which of the following atoms is least reactive?

   a. ^{11}Na b. ^{9}F c. ^{87}Fr d. ^{86}Rn

18. Give the symbol of an element that places its last electron in an s subshell and fills the subshell.

19. Find the symbol of a metal that is more reactive than Ra. Write the symbol.

20. Select the pair of atoms which are least similar in their properties.

    a. ^{17}Cl and ^{18}Ar b. ^{17}Cl and ^{9}F c. ^{17}Cl and ^{53}I

    d. ^{17}Cl and ^{35}Br

21. If an atom of Na loses 1 electron, the electron configuration is:

    a. $1s^2\ 2s^2\ 2p^6\ 3s^2$ b. $1s^2\ 2s^2\ 2p^6\ 2d^1$

    c. $1s^2\ 2s^2\ 2p^6\ 3s^1$ d. $1s^2\ 2s^2\ 2p^6$

22. Which of the following nonmetals is most reactive?

    a. ^{6}C b. ^{7}N c. ^{8}O d. ^{9}F

23. Find an atom in the family with Mg that reacts faster than Mg. Write the symbol.

24. Select the number of atoms of K that react with 1 atom of S to form a compound.

    a. 1 b. 2 c. 3 d. 4

25. Write the formula of the compound containing Al and Se.

26. Give the number of elements in the family with Al that are larger in volume than Al.

27. Predict which of the following reacts with Ca to form a compound.

    a. ^{11}Na b. ^{12}Mg c. ^{17}Cl d. ^{10}Ne

28. Find an element that gains electrons during chemical reactions. Write the symbol.

REFERENCES

Abramson, T., & Kagen, E. Familiarization of content and different response modes in programmed instruction. Journal of Educational Psychology, 1975, 67, 83-88.

Allen, W. H. Intellectual abilities and instructional media design. Audio-Visual Communication Review, 1975, 23, 139-170.

Anderson, G. L. A comparison of the outcomes of instruction under two theories of learning. (Doctoral dissertation, University of Minnesota, 1941). Doctoral Dissertations Accepted by American Universities, 1942, 10, 82.

Armbruster, B., & Anderson, T. Analysis of science textbooks: Implications for authors. Boulder: Paper presented at the conference for Research in Science Education: New Questions, New Directions, 1980.

Bean, W. K. This periodic table has class. The Science Teacher, 1980, 47, 31.

Berry, L. H. The effects of color realism on pictorial recognition memory. Miami Beach: Paper presented at the annual meeting of the Association for Educational Communications and Technology, 1977. (ERIC Document Reproduction Service No. ED 148 319)

Brown, J. L. Effects of logical and scrambled sequences in mathematical materials on learning with programmed instruction materials. Journal of Educational Psychology, 1970, 61, 41-45.

Buckland, P. R. The ordering of frames in a linear program. Programmed Learning and Educational Technology, 1968, 5, 197-205.

Campbell, J. A. Atomic size and the periodic table. Journal of Chemical Education, 1946, 23, 525-529.

Carpenter, C. R. A theoretical orientation for instructional film research. Audio-Visual Communication Review, 1953, 1, 38-52.

Carpenter, T., Coburn, T., Reys, R., & Wilson, J. Results from the first mathematics assessment of the national assessment of educational progress. Reston, Virginia: National Council of Teachers of Mathematics, 1978.

Chase, W. G., & Simon, H. A. Perception in chess. Cognitive Psychology, 1973, 4, 55-81.

Chute, A. G. Analysis of the instructional functions of color and monochrome cuing in media presentations. Educational Communication and Technology: A Journal of Theory, Research, and Development, 1979, 27, 251-263.

Clauson, J. E. A space model of the periodic system of elements. Journal of Chemical Education, 1952, 29, 250-251.

Cronbach, L. J. Individual differences in learning ability as a function of instructional variables. Basic and applied research proposal, submitted to the U.S. Commission of Education, 1965.

Cronbach, L. J., & Snow, R. E. Aptitudes and instructional methods. New York: Irvington Publishers, Inc., 1977.

Dwyer, F. M. A guide for improving visualized instruction. State College, Pennsylvania: Learning Services, 1972.

Dwyer, F. M. Effects of IQ level on the instructional effectiveness of black and white and color illustrations. Audio-Visual Communication Review, 1976, 24, 49-62.

Eichinger, J. W., Jr. The electron chart. Journal of Chemical Education, 1957, 34, 70-71.

Emerson, E. I. A chart based on atomic numbers showing the electronic structure of the elements. Journal of Chemical Education, 1944, 21, 254-255.

Fredrick, W. C., Blount, N. S., & Johnson, S. L. A comparison of verbal statement, symbolic notation, and figural representation of grammar concepts. Madison: Report from Center for Cognitive Learning, University of Wisconsin, 1968. (ERIC Document Reproduction Service No. ED 029 892)

French, J., Ekstrom, R., & Price, L. Kit of reference tests for cognitive factors. Princeton: Educational Testing Service, 1963.

Fry, E. A readability formula that saves time. Journal of Reading, 1968, 11, 513-516.

Gentner, D. The structure of analogical models in science. Washington, D.C.: Report prepared for Office of Naval Research, 1980. (ERIC Document Reproduction Service No. ED 193 011)

Guenther, W. B. An electronegativity spectrum for the periodic table. Journal of Chemical Education, 1970, 47, 317.

Hyde, J. F. Let the elements teach periodic law. The Physics Teacher, 1975, 13, 538-541.

Jensen, A. How much can we boost intelligence and academic achievement. Harvard Educational Review, 1969, 39, 1-123.

Klingenberg, J., & Springman, L. A periodic table showing the relative sizes of elements and their ions. Journal of Chemical Education, 1952, 29, 81.

Koran, M. L. Aptitude, achievement, and the study of aptitude-treatment interactions. Carmel: Paper presented at the CTB/McGraw-Hill Invitational Conference, 1973.

Koran, M. L., & Koran, J. J., Jr. Interaction of learner characteristics with pictorial adjuncts in learning from science text. Journal of Research in Science Teaching, 1980, 17, 477-483.

Kow, T. W. An octagonal prismatic periodic table. Journal of Chemical Education, 1972, 49, 59.

Larkin, J. H. Processing information for effective problem solving. Engineering Education, 1979, 70, 285-288.

Larkin, J. H., McDermott, J., Simon, O. P., & Simon, H. A. Expert and novice performance in solving physics problems. Science, 1980, 208, 1335-1342.

Maier, M. H., & Jacobs, P. I. The effects of variations in a self-instructional program on instructional outcomes. Psychological Reports, 1966, 18, 539-546.

Mazurs, E. G. Graphic representations of the periodic system during one hundred years. University, Alabama: The University of Alabama Press, 1974.

McCutchon, K. B. A simplified periodic classification of the elements. Journal of Chemical Education, 1950, 27, 17-19.

Miller, L. E. A periodic chart based on s p d f electron distribution. Journal of Chemical Education, 1955, 32, 198-199.

Norman, C., & Rieber, M. Facilitation of concept formation in children by the use of color cues. Journal of Experimental Psychology, 1968, 76, 460-463.

Orton, K., McKay, E., & Rainey, D. The effect of method of instruction on retention and transfer for different levels of ability. School Review, 1964, 72, 451-461.

Reese, W. F., & Meek, J. S. The first revolving block periodic table. The Science Teacher, 1961, 28, 47.

Rice, W. E. A helical periodic table. Journal of Chemical Education, 1956, 33, 492.

Salomon, G. Internalization of filmic schematic operators in interaction with learner's aptitude. Journal of Educational Psychology, 1974, 66, 499-511.

Sanderson, R. T. One more periodic table. Journal of Chemical Education, 1954, 31, 481.

Sanderson, R. T. A new periodic chart with electronegativities. Journal of Chemical Education, 1956, 33, 443-445.

Scherer, G. A. Models of a spiral periodic chart. Journal of Chemical Education, 1949, 26, 133-134.

Shoemaker, J. L. History of development of the periodic chart and its use as a teaching aid. Science Education, 1958, 42, 142-151.

Simmons, L. M. Display of electron configuration by a periodic table. Journal of Chemical Education, 1948, 25, 658-661.

Simon, H. A. How big is a chunk? Science, 1974, 183, 482-488.

Sternberg, R. Component processes in analogical reasoning. Psychological Review, 1977, 84, 353-378.

Szabo, Z. G., & Lakatos, B. A periodic table and new periodic functions. Journal of Chemical Education, 1957, 34, 429-432.

Thiele, C. L. The contribution of generalization to the learning of addition facts. New York: Teacher College Contributions to Education, No. 763, Teachers College, Columbia University, 1938.

Tobias, S. Achievement-treatment interaction. Review of Educational Research, 1976, 46, 61-74.

Tobias, S., & Ingber, T. Achievement treatment interactions in programmed instruction. Journal of Educational Psychology, 1976, 68, 43-47.

Travers, R. M. W. Research and theory related to audio-visual information transmission. Washington, D.C.: United States Office of Education Contract No. 3-20-003, 1967.

Travers, R. M. W. A study of the advantages and disadvantages of using simplified visual presentations in instructional materials. Washington, D.C.: Report to the U.S. Office of Education, 1969. (ERIC Document Reproduction Service No. ED 031 951)

Tversky, A. Features of similarity. Psychological Review, 1977, 84, 327-352.

Verbrugge, R. R., & McCarrell, N. S. Metaphoric comprehension: Studies in reminding and resembling. Cognitive Psychology, 1977, 9, 494-533.

Vernon, M. Learning from graphical material. British Journal of Psychology, 1946, 36, 145-157.

Vernon, M. The visual presentation of factual data. British Journal of Psychology, 1950, 40, 174-175.

Wagner, H. A., & Booth, H. S. A new periodic table. Journal of Chemical Education, 1945, 22, 128-129.

Wheelbarger, J. J. An investigation of the role of pictorial complexity in visual perception. (Doctoral dissertation, University of Virginia, 1970). Dissertation Abstracts International, 1971, 31, 5864-A. (University Microfilm No. 71-06636)

Wicker, F. W. Photographs, drawings, and nouns as stimuli in paired-associate learning. Psychonomic Science, 1970, 18, 205-206.

Winn, W., & Schieman, R. The effect of the removal of common meaning on the structure of free association to black and white and color pictures. Miami Beach:

Paper presented at the national convention of the Association for Educational Communications and Technology, 1977.

Wittrock, M. C. The cognitive movement in instruction. Educational Researcher, 1979, 8, 5-11.

Zeaman, D., & House, B. J. The role of attention in retardate discrimination learning. Handbook of mental deficiency. New York: McGraw-Hill, 1963.

BIOGRAPHICAL SKETCH

Born on April 25, 1952, in Lebanon, Pennsylvania, Jeffrey Richard Lehman lived with his parents, Richard and Helen Lehman, and four sisters and brothers, Joanne, Kenneth, Thomas, and Jan. He attended Lebanon Senior High School and upon graduation enrolled at the University of Delaware, Newark, Delaware in 1970.

At Delaware his major was chemistry, and he served as an undergraduate laboratory teaching assistant. Upon graduating with a Bachelor of Science degree, he enrolled in the graduate program at The Pennsylvania State University, in State College, Pennsylvania.

While at Pennsylvania State University, he served as an undergraduate laboratory and recitation instructor in chemistry. Upon graduating with a Master of Science degree with a major in chemistry in 1975, he taught chemistry at Marple-Newton High School in Newton Square, Pennsylvania.

The following year he moved to Red Lion, Pennsylvania, and for three years taught general science and chemistry.

In 1979 he left the public schools and went to Florida to complete his doctoral studies in science education under the supervision of Dr. John J. Koran, Jr.

At the University of Florida he served as a graduate teaching assistant and later as a teaching associate in the Department of Subject Specialization Teacher Education. His responsibilities included teaching undergraduate courses, supervising science interns, assisting in the instructional computing laboratory, and performing teacher center activities in the public schools.

Jeffrey Lehman is married to the former Kathleen Marian Nock.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

John J. Koran, Jr., Chairman
Professor of Subject Specialization
Teacher Education

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Mary Lou Koran
Professor of Foundations of Education

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

William Hedges
Professor of Instructional Leadership
and Support

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Eugene Todd
Professor of Subject Specialization
Teacher Education

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

James Algina
Associate Professor of Foundations of Education

This dissertation was submitted to the Graduate Faculty of the Division of Curriculum and Instruction in the College of Education and to the Graduate Council, and was accepted as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

May, 1982

Dean for Graduate Studies and Research